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DR NO. SE-269
REPORT NO. GDCA-DDA72-007
CONTRACT NAS 8-27539

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

TECHNICAL SUMMARY

GENERAL DYNAMICS
Convair Aerospace Division
San Diego operation

Space Division
North American Rockwell

TRW
SYSTEMS GROUP

Bendix

FINAL RAM DOCUMENTATION

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TECHNICAL SUMMARY

12 May 1972

Approved by *[signature]*
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Program Director

Submitted to
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FOREWORD

This document is the RAM Technical Summary and has been prepared in accordance with NASA Data Requirement DR SE-269. It is a part of the final documentation of Phase B of the Research and Applications Modules (RAM) Program accomplished under NASA Contract NAS 8-27539.

The basic study was conducted from 12 May 1971 to 12 May 1972 with certain studies continuing to 12 August 1972, by a contractor team led by General Dynamics Convair Aerospace and supported by North American Rockwell Space Division, Bendix Navigation and Controls Division, and TRW Systems Group. The RAM team operated under the direction of the RAM Program Office at Marshall Space Flight Center headed by Lowell K. Zoller. Other NASA centers and offices provided significant advice, consultation, and documentation in support of the tasks reported herein. International cooperation and assistance was provided by three European firms: ERNO and Messerschmitt-Bölkow-Blohm (MBB) of West Germany and SAAB-Scania of Sweden. Documentation of these efforts will be submitted to NASA separately.

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RESEARCH AND APPLICATIONS MODULES (RAM)
PHASE B STUDY

SECTION 1

INTRODUCTION

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SECTION 1

INTRODUCTION

The research and applications modules (RAM) system is a family of payload carrier modules that can be delivered to and retrieved from earth orbit by the space shuttle. RAM payload carriers will be capable of supporting diverse technological and scientific investigations and practical applications, primarily in areas requiring man's participation for orbital performance, calibration, servicing, and update.

This document describes the RAM system's capability for implementing a wide range of manned and man-tended missions. RAM concepts were developed by the tasks reported in detail in the three volumes of the Technical Data Document (NASA DR No. 268) and carried through predesign. Configuration and subsystem optimization and selections, together with their supporting analyses and flight and ground operations, are summarized here. The payloads, which were used only to provide design and operations requirements, are selective groupings of the experiments described in the 25 functional program elements contained in NASA document NHB 7150.1, Reference Earth Orbital Research and Applications Investigations (Blue Book), 15 January 1971. A functional program element is a grouping of experiments according to their complementary scientific dependence, synergism, or data return and their similar and related demands on RAM elements or space station support systems.

The experiment, mission, and programmatic requirements (together with guidelines and constraints provided by NASA) led to the evolution of three basic RAM system elements: pressurized RAMs, unpressurized RAMs, and pressurizable free-flying RAMs. These elements, which are compatible with space shuttle and are manned or man-tended modules capable of supporting a diversity of scientific, applications, and technological investigations, have wide application to a broad range of earth orbital missions and are not limited to the payload groupings used in their derivation. Figure 1-1 shows a Reference Experiment Plan provided by NASA for use as a baseline in the derivation and planning of the RAM project. This plan describes the number and frequency of shuttle flights dedicated to RAM missions and the RAM payloads for the identified flights. It is used to judge programmatic requirements, such as the number of articles (RAM elements) required, operations requirements, and time phasing of RAM elements.

1.1 STUDY OBJECTIVES

The overall objective of the RAM project is to provide versatile and economical laboratory and observatory facilities that complement and supplement the space station and/or space shuttle in earth orbital research and applications activity.

	YEAR	78	79	80	81	82	83	84	85	86	87	88	89	90
EARLY OPERATIONAL CAPABILITY	SPACE SHUTTLE		▲											
	INITIAL SPACE STATION				▲									
	GROWTH SPACE STATION								▲					
SORTIE MISSIONS	PHYSICS & ASTRONOMY		1	2	3	5	5	4	5	4	5	4	5	5
	LIFE SCIENCES		1	1	1			1	1					
	EARTH OBSERVATIONS			1	2	2	2	4	4	2	2	2	3	3
	COMM & NAV				1	1				1		1		
	TECHNOLOGY & MATERIALS SCIENCE			2	1	2	1	1		2		2	1	1
MAINTAINED OBSERVATIONS (FREE-FLYING)	HEAO		X			X	Y		X		Y		X	
	REVISITS			2	2	2	2	2	2	2	2	2	2	2
	LARGE SPACE TELESCOPE				X				YX					
	REVISITS					2	2	2	1	2	2	2	2	2
	LARGE SOLAR OBSERVATORY						X					YX		
	REVISITS							2	2	2	2	1	2	2
ATTACHED TO STATION	PHYSICS LAB						X			Y		X		
	COSMIC RAY LAB											X		
	LIFE SCIENCES LAB				X		Y		X					Y
	EARTH OBSERVATION LAB				X		Y		X					Y
	COMM & NAV						X		Y					X
	TECHNOLOGY & MATERIALS SCIENCE LAB													X
	SHUTTLE FLIGHTS		3	8	13	14	18	16	22	18	16	20	18	21

NOTE: X = LAUNCH Y = RETURN FOR REFURBISHMENT (INCLUDED IN SHUTTLE FLIGHT SUMMARY)

Figure 1-1. Baseline Reference Experiments Plan

From the user's viewpoint, an important program objective is to provide convenient and complete laboratory facilities with which it is easy to interface and to which rapid access is possible for independent research and applications specialists in government, universities, and industry. In conjunction with this is a desire to provide a practical mechanism by which international cooperation and participation in space research can be achieved.

1.2 SCOPE AND TASK APPROACH

The major RAM study considerations depicted in Figure 1-2 illustrate the evolutionary characteristics of the RAM system. RAM payload carriers will be responsive to the requirements of the user community and to the availability of resources. Planning is based on minimum early funding, maximum use of existing hardware, and early applied benefits. It is assumed that the space station will be introduced eventually and that maximum use of the space shuttle with pressurized, unpressurized, and pressurizable free-flying RAMs will be made in the interim.

When the space station is available for use in addition to the shuttle, it will provide extended-time research capability, maximum RAM facility and laboratory support, and maximum user participation. Pressurized RAMs configured for use with the shuttle can, in many instances, be used in conjunction with the space station.

- MINIMUM EARLY FUNDING
- MAXIMUM USE OF EXISTING HARDWARE
- EARLY APPLIED BENEFITS
- EXTENDED TIME RESEARCH CAPABILITY
- MAXIMIZE FACILITY & LAB SUPPORT
- MAXIMUM USER PARTICIPATION

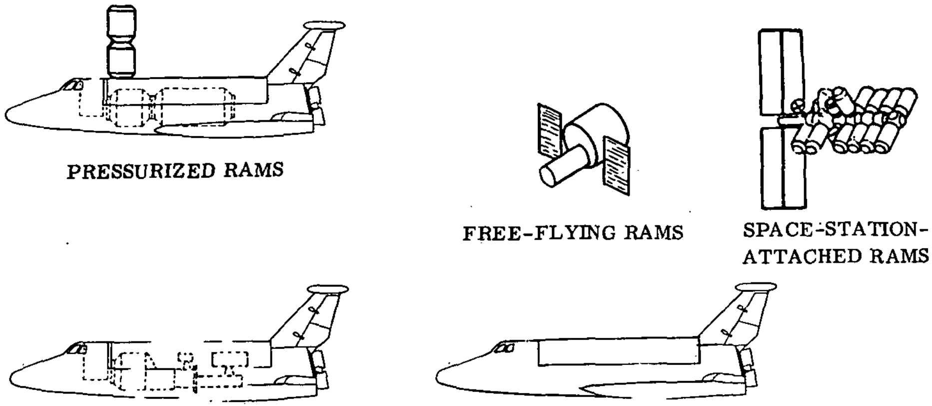

Figure 1-2. Major RAM Study Considerations

The RAM Phase B study has five major tasks. Figure 1-3 summarizes the data generated in each task and the task output. The output of Task 4.1 was a consolidated set of requirements covering payloads, missions, and support systems. From these requirements, conceptual payload carriers used to establish feasibility for the mission analysis were identified. These requirements were used to synthesize families of RAM payload carriers to satisfy a variety of candidate programs.

TASK 4.1	TASK 4.2/TASK 4.3	TASK 4.4 & 4.5
• REFERENCE PAYLOAD SELECTION & DEFINITION • PAYLOAD ACCOMMODATIONS • MISSION & OPERATIONS REQUIREMENTS • RAM SENSITIVITY TO SHUTTLE & STATION VARIATIONS	• RAM SYSTEMS CONSISTING OF PAYLOAD CARRIERS • EXPERIMENT PLAN VARIATIONS • COMMONALITY • PRELIMINARY COSTS • ANALYSES OF RAM SYSTEMS • COST SENSITIVITY & AVOIDANCE • SYSTEMS INTEGRATION & INTERFACES • EXPERIMENT VARIATIONS • OPERATING & FLIGHT CHARACTERISTICS	• RAM ELEMENT CONFIGURATION DESIGN • SUBSYSTEM DESIGN • EXPERIMENT INTEGRATION • OPERATIONS • SYSTEM ELEMENT & TOTAL SYSTEM COSTS • DRAWINGS & MOCKUPS • RELIABILITY/ MAINTAINABILITY • SAFETY
• DESIGN & MISSION REQUIREMENTS • OPERATIONAL APPROACHES • CANDIDATE PAYLOAD CARRIERS	• RECOMMENDED SYSTEM OF RAM ELEMENTS	• PRELIMINARY DESIGN OF RAM SYSTEM ELEMENTS • PROJECT DEFINITION PLAN

Figure 1-3. RAM Study Approach

From Task 4.2, the study team selected families of payload carriers (systems) for further analysis in Task 4.3, emphasizing the areas indicated on the chart. The objective of this work was to perform the tradeoffs that allowed selection of the minimum number of RAM elements for preliminary design that would provide the maximum selectivity and flexibility in accommodating the technical and programmatic requirements and potential variations.

In Tasks 4.4 and 4.5, a preliminary design (definition to WBS Level 6) and the project development requirements of the selected RAM system elements were generated. In addition to the overall habitability analyses of the RAM payload carriers, full-scale soft mockups generated during this task were used to proof some of the equipment arrangements and access provisions for maintenance. Figure 1-4 illustrates the general study flow of the work reported in this volume and associated final documentation.

1.3 SELECTED RAM FAMILY OF PAYLOAD CARRIERS

The selected RAM concept is a family of payload carrier modules that can be delivered to and returned from earth orbit by the space shuttle and that allows flexibility in performing a research and applications experiment plan. Low early-year funding requirements and the selection of experiments leading to early practical applications were given primary consideration in the evolution of the selected RAM concept. RAM payload carriers can function in both a shuttle-supported and space-station-supported mode. The Reference Experiments Plan, provided by NASA, was used as a programmatic baseline in the derivation of RAM project costs and plans.

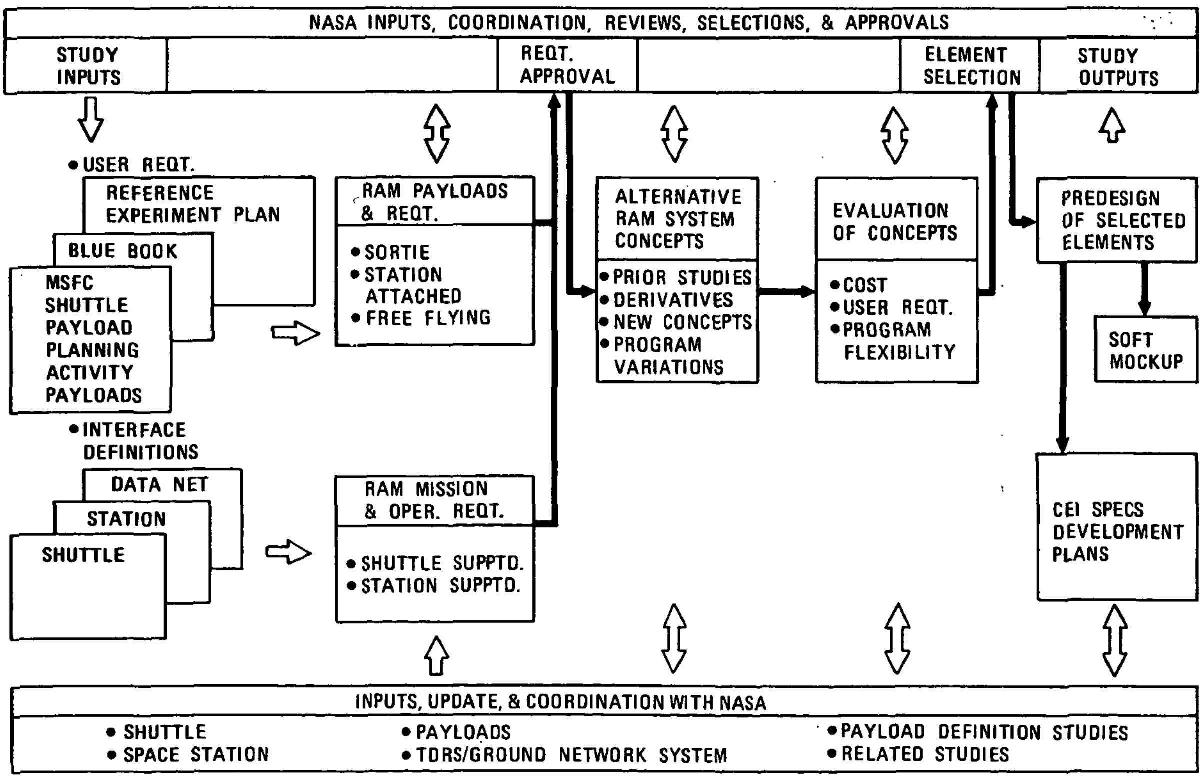

Figure 1-4. RAM Phase B Study General Study Flow

In conjunction with experiment/payloads derived from the Blue Book, the missions and operations analyses formed the basis for subsystem resource requirements to be provided by RAM payload carriers. Figure 1-5 is a composite RAM mission scenario showing the three derived mission modes: sortie, station-attached, and free-flying. The characteristics of these mission modes are:

a. Sortie RAM Mission. The RAM payload carrier remains attached to the shuttle during this short-duration mission (nominally seven days). Sortie mission payloads are compatible with the shuttle environment, and are well adapted for payloads that maximize early scientific and applications returns. Sortie RAM, sortie RAM/RAM pallet, RAM support module (RSM)/RAM payload module, and RSM/RAM payload module/RAM pallet combinations of RAM elements have applications in sortie missions.

b. Free-Flying RAM Mission. The RAM payload carrier is automated, unmanned, and free flying during experiment periods, but is serviced on-orbit periodically by man. This servicing can be performed by either periodic visits by shuttle or periodic visits by the payload carrier to the space station. Free-flying RAM payloads are characterized by extended observation periods with requirements for extreme stability and a contamination-free environment. RAM elements with applications to this mission mode are the free-flying RAM as a payload carrier and the sortie RAM.

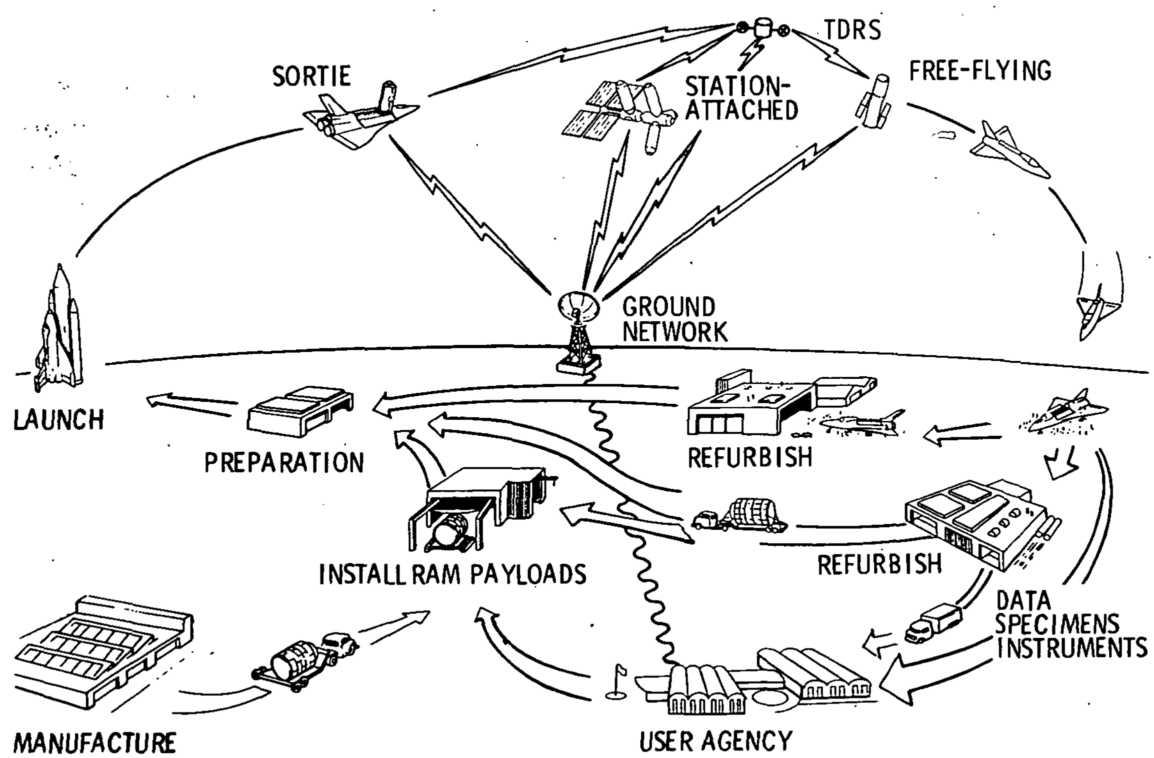

Figure 1-5. RAM Missions

for on-orbit servicing of the free-flying RAM. The payload carrier may be periodically returned to earth for refurbishment and reuse.

c. Station-Attached RAM Mission. The RAM payload carrier remains attached to the space station during experiment operations. Crew habitability and subsystem support for operations and servicing (except for thermal control) are supplied by the space station, which is a set of modules interconnected in multiples to provide core subsystems, crew living quarters, electrical power, and other operational capabilities. Station-attached payloads require extensive manned attention over extended experiment periods.

Figure 1-6 is representative of the typical experiment/payload subsystem resource requirements. Other important design factors are the interfaces with other systems including the space shuttle, the space station, and the ground network system. For example, the physical size of RAM payload carrier is limited by the size of the shuttle orbiter cargo bay, which has physical dimensions of 15 feet in diameter and 60 feet in length. The RAM payload carrier is limited to 14 feet in diameter and 58 feet in length, with protuberances extending to the limits of shuttle cargo bay envelope in some versions.

Resources are sized at effective levels based on payload and housekeeping requirements and consideration of equipment available from other programs. Minor adaptation for specific missions will be accomplished using standardized payload integration equipment to satisfy unusual or additional subsystem resource requirements. A high degree of commonality is maintained between different RAM payload carriers.

The selected RAM family of payload carriers consists of three basic elements: pressurized, unpressurized, and pressurizable (free-flying) RAMs. The pressurized element provides an enclosed, protective space in which scientific research can be performed in a shirtsleeve environment. There are three specific derivatives, each with a specific capability and designed for a specific role. These derivatives have a high degree of commonality; for example, they use a common structure and can be converted from one configuration to another. The three adaptations of the pressurized RAM include the sortie RAM, RAM support module (RSM), and RAM payload module.

a. Sortie RAM. A pressurized RAM that remains attached to the shuttle orbiter and is configured to provide a basic laboratory capability to accept experiments and instrumentation for a multiplicity of disciplinary areas to be flown on shuttle sortie missions of typically seven days' duration. (Longer-duration missions are possible through the provision of additional expendables.) The sortie RAM provides the required subsystem resources and services beyond those provided and used from the shuttle.

b. RAM Support Module (RSM). A pressurized RAM that remains attached to the shuttle and provides accommodations for added crew (payload and/or mission specialists) and serves as the interface between the shuttle and other RAM elements. The RSM can provide or distribute to other modules such subsystem resources and

services as electrical power, thermal control, environmental control, life support, and habitability.

The RSM provides the required subsystem resources and services beyond those provided and used from the shuttle.

c. RAM Payload Module. A pressurized RAM adaptation providing additional volume for RAM payload installation. The RAM payload module operates attached to the sortie RAM, RSM, or space station, and hence has minimal autonomous subsystem provisions.

   1. Space-Station-Attached RAM Payload Module. Designation for a RAM payload module that operates attached to a space station, is pressurized to a shirt-sleeve environment, and receives life support, power, and other support from the space station. Such RAM payload modules are normally configured to provide a comprehensive laboratory capability in one or more disciplines and are intended to remain attached to the space station for extended durations.

   2. Sortie RAM Payload Module. Designation for a RAM payload module that is used in conjunction with a sortie RAM or RSM, is pressurized to a shirt-sleeve environment, and receives life support, power, and other support from the aforementioned modules. Sortie RAM payload modules are configured to provide flexibility for accommodating various experiments/payloads with minimum turnaround time.

The unpressurized element (RAM pallet) is used in the sortie mission mode for experiments with large equipment that requires outside mounting (such as telescopes). It always operates attached to a pressurized RAM element and generally depends on the pressurized RAM element for system support, although some mission-unique subsystems may be required. Manned accessibility to the RAM pallet on orbit will require extravehicular activity.

Experiment payloads that require long stay times in orbit, extreme pointing/stability accuracies, and minimum environmental contamination are accommodated by the third RAM element: a pressurizable (free-flying RAM). This element uses subsystem equipment common to the other RAM elements but has additional capability such as propulsion and guidance, navigation, and control. Because of the economic benefits, the free-flying RAM (which operates on-orbit in an unmanned, automated mode) is designed to facilitate on-orbit manned repair, maintenance, and refurbishment; thus, it is capable of being pressurized for manned access. Periodic servicing can be performed by visits to the free-flying RAM by the shuttle using a pressurized RAM element for the manned support or visits to the free-flying RAM by the space station. In either case, the free-flying RAM will draw required support during periods of man servicing from the pressurized RAM element or space station, as applicable.

A RAM project can be implemented with a single pressurized element (the sortie RAM), which can evolve into other pressurized derivatives to provide the desired degree of

capability as needed. RAM pallet and free-flying RAM elements can be progressively introduced into the program when needed for specific types of payloads. The RAM subsystems were defined to permit maximum use of hardware from other programs whenever it is proven cost effective. The subsystems provide a nominal capability that can be readily expanded through the use of modular subsystem add-ons. A description of the capabilities and characteristics of each of the RAM elements is presented in Sections 2.4 and 3.0.

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 2

PROGRAM DEFINITION

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SECTION 2

PROGRAM DEFINITION

This section defines the overall RAM project goals, guidelines, schedules, and baseline mission profiles that provided the basis for selecting the RAM system concept. In addition, a summary description of the selected RAM elements is presented.

2.1 PROJECT GOALS

The major RAM project goals are to:

a. Provide payload carrier (RAM) concepts that complement and supplement the space shuttle and/or space station systems with minimum sensitivity to variations in these systems' definitions.

b. Provide versatile, economical, and scientifically responsive laboratories and observations (RAM) for exploration and utilization of space.

c. Provide a flexible payload carrier (RAM) system concept insensitive to variations in program implementation, funding, and schedules.

d. Foster international participation and cooperation in space research.

e. Meet the overall and specific needs of the user community — governmental, educational, industrial, and international — through reasonable cost, simplified interfaces, and short lead time in operating experiments in the space environment.

2.2 GUIDELINES AND CONSTRAINTS

The NASA supplied contractor guidelines for the RAM project are contained in Table 2-1. These guidelines were the foundation for developing system requirements used in producing conceptual designs and project costs.

2.3 DERIVED SYSTEM REQUIREMENTS (PAYLOADS)

This section summarizes payload classifications, mission modes and applicability of payloads to RAM elements, representative payload and requirements, derived mission/operations requirements, payload integration equipment requirements, and user requirements.

2.3.1 PAYLOAD CLASSIFICATION. For mission planning and the subsequent identification of mission operations requirements, it is convenient to group payload activities into three areas, each with its own set of orbital and orientation conditions: processes in zero-g, earth measurements, and celestial observations (Figure 2-1).

Table 2-1. Contractor Guidelines for RAM Project

CONTRACTOR GUIDELINES
FOR
RAM PROJECT

1.0 PROGRAM

1.1 The Research and Applications Modules (RAM) Project includes the design, development and operation of RAMs, accommodating selected or partial Functional Program Elements (FPE) which can be transported to and from orbit internal to the Shuttle. The RAM is a project element of the Space Station Program.

1.2 NASA will provide a Reference Experiment Program (REP) for the purpose of project planning and cost estimating. The plan will include a schedule of RAM launches commencing with the Shuttle IOC of July 1979 and continuing through 1990. An Initial Capability (IC) Space Station IOC date of July 1981 and a Growth Space Station IOC date of July 1985 will be used to schedule RAMs. The REP may be revised by NASA, as appropriate, based on study results.

1.3 The RAMs will be designed to operate in the two mission modes below:

1.3.1 Shuttle Supported Mode — In this mode the RAMs will operate attached to the Shuttle for periods up to 7 days. Consideration may be given to missions of longer duration. However, requirements for these missions shall be thoroughly defined and an assessment made of their impact on RAM and Shuttle. Free flying RAMs will also operate with periodic revisits by Shuttle.

1.3.2 Space Station Supported Mode — In this mission mode, the RAMs operate attached to the Modular Space Station or detached in a free flying mode with the Modular Space Station supporting their operation.

1.4 A RAM Support Module (RSM) which supports RAMs in the Shuttle Supported Mode, and is the physical interface between the Shuttle and RAMs, will be designed as an element of the RAM project. The RSM will remain attached to the Shuttle throughout a given mission and may provide power, environmental control and life support, data management, habitability and other services as required.

1.5 Commonality is a primary consideration throughout the study. As a goal, common module systems and subsystems, assemblies, tooling, GSE and software for Shuttle, Space Station modules, logistics modules, and RAM should be developed.

1.6 The development approach will provide the basis for reducing the number and cost of test articles and major tests and will provide for utilization of the Shuttle for on-orbit testing as required.

1.7 The coordinate axes and reference planes shall be in accordance with Appendix G, Change 9, dated November 13, 1970, Space Shuttle Level II Requirements, June 15, 1970.

1.8 As a goal, the RAM designs and operational concepts will be compatible with both Phase B Shuttle and both Phase B Modular Stations (reflecting both Center's design approaches). NASA will provide the contractor with Space Station and Shuttle Data packages.

1.9 Natural environment data specified in NASA TMX 53865, 53872, and 53957 will be used.

2.0 COST

2.1 The Standard Cost Format (SCF) furnished to the contractor under the Government Furnished Data Requirements section of the contract shall be used for reporting cost estimates as required by NASA Headquarters for programmatic information and is in addition to the other contractual reporting requirements. The SCF is a recapitulation of cost estimates generated for the Work Breakdown Structure (WBS) and will not exceed the depth of the WBS.

2.2 Changes in non-recurring and recurring costs as a function of changes in peak production rates required by the REP (1.2) will be defined.

2.3 A major objective in the scheduling of FPEs, or partial FPEs, selection of accommodation modes, and the sequence of RAM development and operations will be to minimize early year funding requirements.

2.4 The contractor will show the relationship between non-recurring costs for the different types of RAMs in the event that one or more types are deleted.

2.5 For cost estimating purposes, assume that all RAMs are developed and produced by one prime contractor.

2.6 Costs of experiment integration shall be assigned to the prime contractor. This will not constrain integration of selected experiments at the launch site.

2.7 Return and refurbishment of modules and/or experiments shall be costed and the activity assumed to be conducted by prime contractor.

2.8 Ground test articles for crew training and other purposes shall be assumed to be developed, operated and maintained by the prime contractor.

2.9 Ground support equipment, tooling, and special test equipment shall not be assumed to be available from prior programs. However, the contractor will identify and cost separately modifications to existing inventories.

2.10 Construction and maintenance costs for new, modified, or additional facilities are to be provided by the contractor.

2.11 Project level comparisons will be performed by applying a 10% discount factor. This factor will be used also in critical cost tradeoff studies determined jointly by the contractor and the NASA COR. The base year for discounting will be the Government fiscal year of Phase C initiation.

2.12 Effects of cost avoidance techniques will be treated and displayed as increments from baseline costs at the project element (module) level.

2.13 Cost of all spares are to be identified separately but characterized as operations costs.

2.14 The contractor will not furnish costs for use of the basic Ground Network and Synchronous Satellite Communications System. (A detailed description of this basic system will be furnished by NASA). However, the contractor will obtain from the contracting officer and include in the report the following estimates: (a) costs of any modifications proposed by the contractor to this basic system; (b) costs of any modifications proposed by the contractor to other (existing) ground operations support facilities; (c) increased operations costs as a result of the above modifications; (d) costs of development and operation of any special ground facilities needed, including special communications.

2.15 Cost data for FPEs and partial FPEs will be furnished by NASA.

2.16 RAM Project cost data will be developed around the philosophy of "shared development costs," which assigns development costs to only one program or project. For RAM those subsystem, system or component development costs which reflect developments by other programs such as Shuttle, Space Station or other project will be separately identified and will be included in total RAM Project costs in such a manner that full identification of costs to the Agency with and without shared costs can be ascertained. Where interproject commonality is involved, both non-recurring and recurring costs will be identified. Such development cost sharing should be accompanied by an indication of precedence of development among the various projects or programs. Thus, development costs for a growth

station subsystem or assembly, time-phased later than RAM, should be identified as a shared cost with RAM since both would use the same item. The contractor should develop a methodology to indicate how this approach to cost has been incorporated.

3.0 SAFETY

3.1 Safety is a mandatory consideration throughout the total project. As a goal, no single malfunction or credible combination of malfunctions and accidents shall result in serious injury to personnel or prevent crew refuge to a habitable area.

3.2 RAM shall be designed such that it can be isolated at the attachment plane from any attached pressurized compartment in case the RAM is damaged or rendered untenable.

3.3 For those hazards that may result in time-critical emergencies, provisions shall be made for automatic switching to a safe mode and to display caution and warning to personnel.

3.4 Two or more suited crewmen will participate in any pressure suit activity and emergency rescue provisions will be provided. The modules shall be designed to minimize pressure suit operations.

3.5 The atmosphere constituents will be monitored for harmful contaminants in each habitable area.

3.6 All materials selected for use in habitability areas will be non-toxic, non-flammable and non-explosive to the maximum extent practicable.

4.0 INTERFACE

4.1 The "design-to" dry weight of individual RAM modules shall not exceed 20,000 pounds when fully outfitted. Total allowable launch weight of RAMs on a single Shuttle shall not exceed 80% of the Shuttle performance to orbit for a given mission. The excess of allowable launch weight over the "design-to" dry weight may be utilized to accommodate expendables and RSM. The RSM shall not exceed 12,000 pounds.

4.2 The "performance reference" weight to be used in RAM subsystems design shall be 40,000 pounds.

4.3 The maximum external dimensions of the modules shall be 14 ft in diameter and 58 ft in length. Mechanisms that are external but attached to the module, such as handling rings, attachments for deployment, docking mechanisms, storage fittings, thrusters, etc., shall be contained, at launch, within an envelope of 15 ft. diameter and 60 ft length.

4.4 Docking ports shall provide a nominal internal diameter of five feet and provide utility interfaces within the pressurized volume.

5.0 OPERATIONS

5.1 RAMs will be unmanned in the free flying mode.

5.2 Maintenance and repair will be accomplished on the ground when cost effective. Module return will be traded against on-orbit repair and replacement.

5.3 Pre-launch and launch operations will be developed to require minimal access to the RAM while on the launch pad.

5.4 As a goal, free flying RAMs will be designed to facilitate their retrieval and recovery by the Shuttle in case of failure of critical on-board systems.

6.3 As a design goal, the contamination of sensors and/or instruments by RAM effluents should be eliminated or minimized by selection of materials, design approaches, and operating procedures.

7.0 SYSTEMS/SUBSYSTEMS

7.1 GENERAL

7.1.1 RAMs development will be based on subsystems and components that minimize initial project costs.

7.1.2 In addition to ground checkout, on-board subsystems will be capable of on-orbit checkout controlled from the Space Station, the RSM in the Shuttle or from the ground.

7.1.3 Critical on-board RAM and RSM systems will be designed to minimize risk of loss of modules, injury to crew, or damage to Shuttle, Space Station or Space Tug.

7.1.4 The module structure and subsystems will be designed to accommodate a nominal operating pressure of 14.7 psia in the habitable areas. Repressurization of RAM elements will be provided by the Space Station for station-attached RAM elements.

7.1.5 The life support and environmental control subsystems for modules that operate attached to the Shuttle shall maintain carbon dioxide (CO_2) partial pressure at a nominal 5.0 MM Hg within a range of 0-7.6 MM Hg.

7.1.6 During operations the attached RAMs will utilize Space Station or RSM and Shuttle subsystems for electrical power, guidance and navigation, stabilization control, atmospheric composition control/life support, communications, etc.

7.1.7 RAMs subsystem shall include provisions for passivation and safing as required for retrieval and recovery operations.

7.1.8 As a goal, no orientation restrictions will be imposed by subsystems.

7.2 IMS

7.2.1 The free flying RAM must be able to communicate with the Shuttle, RSM, or Space Station, and the Ground Network and Synchronous Satellite Communications System, but not necessarily simultaneously. Interruptions in data communications with ground network for as long as five hours will be acceptable.

7.2.2 A synchronous satellite communications system will be available and provide wideband data as well as voice bandwidth communications. (A description of this system will be furnished by NASA.) Reception of wideband data, as required, should be divided between ground network stations and the synchronous satellite communications system. This division will be determined by cost considerations (see 2.3) and experiment requirements.

7.2.3 Free flying modules will be designed to accept and respond to guidance and navigation control from the Shuttle, Space Station or ground. The Shuttle or the Space Station shall control rendezvous and docking of RAMs.

8.0 EXPERIMENTS

8.1 The January 15, 1971 "Blue Book", Reference Earth Orbital Research and Applications Investigations, NHB 7150.1, will be the basis for defining the payloads (experiment/equipment) for the RAMs. Modification to the FPEs as defined in the "Blue Book" will require NASA concurrence. Payloads may consist of combined, partial or complete FPEs.

8.2 Maximum use will be made of standard laboratory equipment where cost effective. Modification and space qualification testing will be minimized.

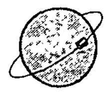
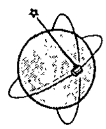
PAYLOAD INVESTIGATION AREA	TYPICAL OBJECTIVES	PRIMARY MISSION REQUIREMENTS
PROCESSES IN ZERO-g • MATERIALS • LIFE SCIENCES • PHYSICS • CHEMISTRY • TECHNOLOGY	APPLICATION TO EARTH PROCESSES SPACE PROCESSING FACILITIES	LOW-g ENVIRONMENT LONG EXPERIMENT PERIODS 
EARTH MEASUREMENTS • SURFACE • ATMOSPHERIC • MAGNETOSPHERIC • COMMUNICATIONS	EARTH INVENTORY & FORECASTING ADVANCEMENT OF COMM/NAV SYSTEMS	STABLE PLATFORM – SHORT OBSERVATION PERIODS GLOBAL COVERAGE 
CELESTIAL OBSERVATIONS • SOLAR • STELLAR • INTERSTELLAR	SOLAR PROCESSES EXTENT & CONTENTS OF UNIVERSE ENERGY FORMS & SOURCES	STABLE PLATFORM - LONG OBSERVATION PERIODS OPTIMIZE VIEWING CONTAMINATION-FREE ENVIRONMENT 

Figure 2-1. Primary Mission Requirements for Various RAM Payloads

2.3.1.1 Process in Zero-g. Materials Science, Life Sciences, Physics, Chemistry, and Technology disciplines are represented in these payloads. The primary payload requirement is a low-g environment. Payloads requiring long experimentation periods at low-g conditions are best accommodated in the station-attached mode. Meaningful information, however, can be obtained for a significant number of payloads over the shorter experimentation periods available in the shuttle-supported mission mode. Typical objectives are the development of new processes (or advancements in existing processes) for possible application on earth and the development of processing facilities for use in space.

2.3.1.2 Earth Measurements. These payloads include communications experiments and measurements of the earth surface, atmosphere, and magnetosphere. Earth measurements payloads are characterized by requirements for a stable platform for short observation periods. Since global coverage is desirable, both the station-attached and sortie mission modes are applicable for these payloads. (The sortie mission provides flexibility in the selection of orbits.) Typical operational objectives are inventorying and forecasting earth resources for direct benefit of mankind and the advancement of communications and navigation system technologies.

2.3.1.3 Celestial Observations. These payloads provide for observation of solar events and the investigation of stellar and interstellar target areas. Primary celestial observations requirements are a stable platform for extended observation periods with optimized viewing angles and a contamination-free environment. These payloads are well adapted to the free-flying mission mode; however, many payloads can be adequately accommodated in the sortie mission mode for early scientific return and as a precursor for observation techniques and equipment.

2.3.2 REPRESENTATIVE PAYLOADS AND REQUIREMENTS. Early in the study, a set of representative RAM payloads was defined by the RAM team with NASA concurrence and direction. Payload goals, objectives, operations, environments, equipment, and data outputs were then analyzed in detail to establish payload capabilities and to define derived requirements placed by the payloads on interfacing systems. Mission and operations analyses have resulted in the definition of characteristics and capabilities for three candidate RAM mission modes: sortie, free-flying, and station attached.

Mission capabilities were then compared with the requirements for each payload to determine the mission modes that best meet payload requirements.

Requirements for the representative RAM payloads have been identified and are summarized in Section 6 in terms of:

a. Physical. Total weight and volume, internal weight and volume.

b. Mission. Orbit, orientation, pointing, stability, and viewing.

c. Resource. Crew, power, and data.

d. Environment. Acceleration, contamination, thermal and radiation.

These payloads adequately represent the broad spectrum of desired experiments while considering such constraints as physical limitations, common facilities, environment, orbits, and similar resource demands. Analysis of this group of payloads has been particularly beneficial in establishing basic subsystem capabilities for each RAM element.

The curves shown in Figures 2-2 and 2-3 summarize the range and distribution of two payload resource requirements for representative RAM payloads. These curves are an example of the technique used to analyze the payload requirements (summary in Section 6) for input to design requirements.

2.3.3 MISSION REQUIREMENTS. Primary RAM missions are depicted in Figure 2-4, which summarizes the RAM mission requirements for each of the mission modes identified for the accommodation of RAM payloads. Orbit characteristics reflect both payload requirements and current shuttle capability. In general, orbit maintenance is provided by the shuttle for sortie RAM missions and for free-flying RAM missions below about 350 n.mi. altitude. Orientation requirements vary by mission mode, with the RAM payload-carrier-supplied inertial orientation for free-flying RAMs as the driving orientation requirement. Active rendezvous and docking capability by RAM payload carrier is required only in the station-supported, free-flying RAM mode. Power

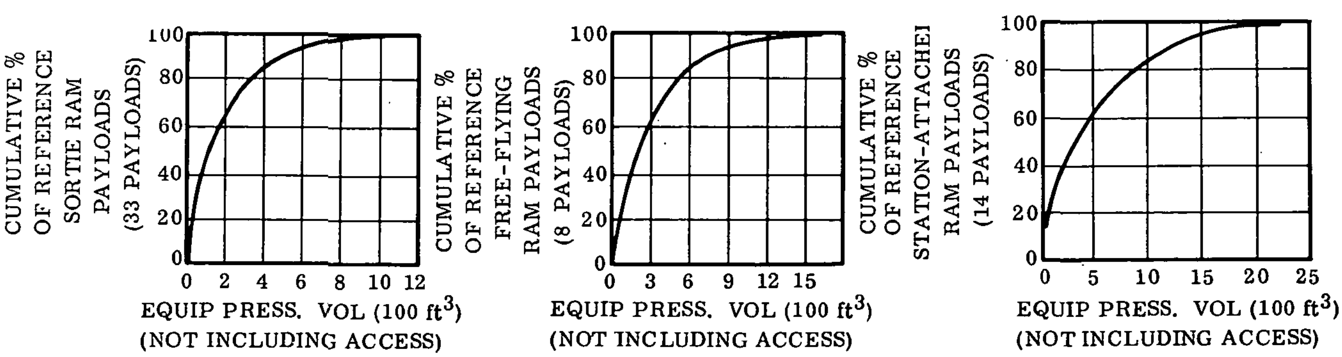


Figure 2-2. Experiment Equipment Pressurized Volume for Representative RAM Payloads

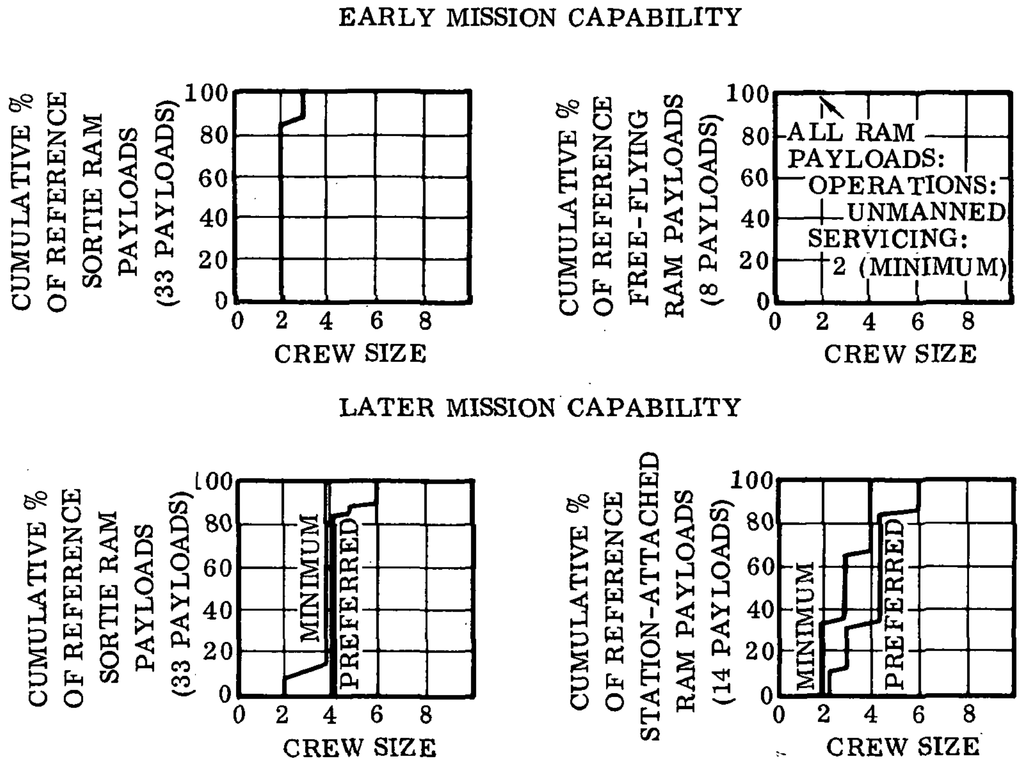


Figure 2-3. Representative RAM Payload Crew Size Requirements

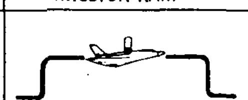
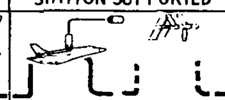
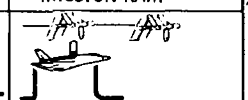
ITEM	SORTIE MISSION RAM	FREE FLYING MISSION RAM		STATION-ATTACHED MISSION RAM
		SHUTTLE SUPPORTED	STATION SUPPORTED	
				
ORBIT ALT. – N.MI.	100 - 400	300 - 400	240 - 270	240 - 270
ORBIT INCL. - DEG.	28.5 - 97	28.5 - 55	55	55
ORBIT MAINTENANCE	BY SHUTTLE <120 N.MI.	BY SHUTTLE <~350 N. MI.	INTERMITTENT - BY RAM	INTERMITTENT - BY STATION
ORIENTATION	VARIOUS – BY SHUTTLE	INERTIAL – BY RAM	INERTIAL – BY RAM	VARIOUS – BY STATION
RENDEZVOUS & DOCKING	——	ATTITUDE CONTROL	ATTITUDE AND ΔV CONTROL	BY SHUTTLE
PAYLOAD RESOURCES	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER DISTRIBUTION DATA HANDLING HEAT REJECTION
COMMUNICATIONS	TDRS/GROUND NETWORK SYSTEM	TDRS - SERVICE MISSION	STATION	STATION
SERVICING	GROUND	SERVICE MISSION	STATION	STATION
PAYLOAD CREW SERVICE CREW	2 TO 6 ——	UNMANNED 2 (MINIMUM)	UNMANNED 2 (MINIMUM)	2 TO 6 2 (MINIMUM)

Figure 2-4. Primary RAM Mission Requirements

generation, data handling, and heat rejection capability are required in all mission modes. For shuttle-supported free-flying RAM missions, the RAM-to-ground communications link is direct to TDRS (Figure 2-5); in the station-supported mode, the communication link is to the space station, where data may be processed, stored, or relayed directly to TDRS (Figure 2-6). On-orbit servicing is required in station-attached and free-flying RAM mission modes; servicing for the sortie RAM mission is performed on the ground. Free-flying RAM missions are unmanned during their long-duration on-orbit experimentation periods; a minimum of two payload crewmen are required for on-orbit servicing. Payload crew requirements for sortie and station-attached missions range from two to six.

The RAM payload carrier subsystem impacts identified through missions and operations analyses are summarized in Table 2-2.

2.3.4 PAYLOAD INTEGRATION EQUIPMENT REQUIREMENTS. Payload integration equipment is provided as required to complete installation of experiment equipment and RAM payload carrier subsystems. This equipment includes 1) experiment integration equipment necessary to install the equipment in the carrier and 2) subsystem add-ons constituting modular additions to basic capabilities.

Payload integration equipment items are not generally specified in experiment definitions, but are needed to support unique payload characteristics or adapt the payload to the RAM carrier or mission. Basic subsystem capabilities have been established through analysis of experiment requirements. A primary consideration was to satisfy a maximum number of payloads while eliminating excess subsystem capability

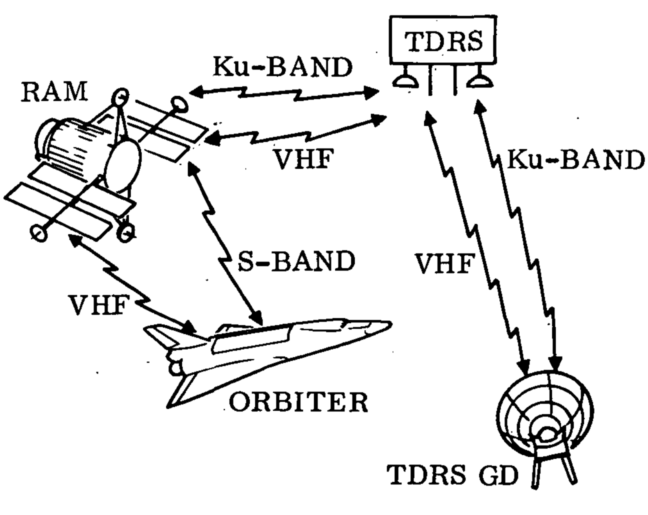


Figure 2-5. Free-Flying RAM Supported by Shuttle/TDRS

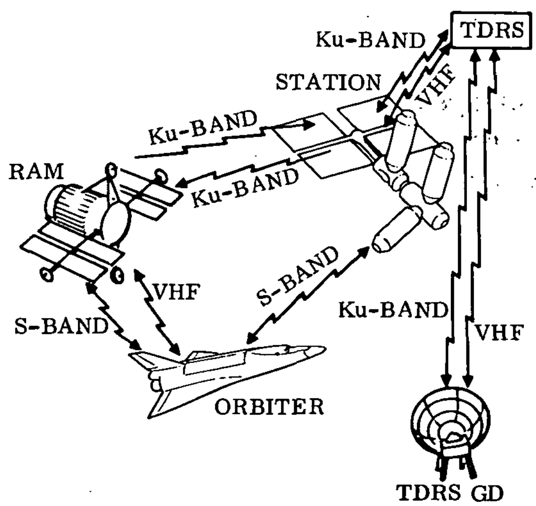


Figure 2-6. Free-Flying RAM Supported by Space Station

Table 2-2. Impact of Key Mission Operations on RAM Payload Carrier Subsystems

Subsystem	Mission Phase				
	Prelaunch	Boost (Entry) and Preparation	On-Orbit Operations	Servicing	Postflight
Electrical Power	Ground Interface and Test	Reduced Load	Full Load	Full Load	Reduced Load
Thermal Control	Ground Interface and Test	Reduced Load Bay Environment	Full Load Space Environment	Full Load Space Environment	Reduced Load Bay Environment
Structure	Transport Loads Handling Fittings Vertical-Horizontal Access	Flight Loads Deployment/Retraction Positive Pressure Vent Interface	Docking Loads Maneuver Loads	Storage Zero-g Access	Data Removal Crew Egress Standard Interface
EC/LS	Ground Interface and Test	Crew Support	Crew Support	Crew Support	Crew Support
Habitability	Ground Operation	Up to 4 Crew	Up to 4 Crew	2 Crew	Ground Operation
GN&C	Ground Test	CMG Spinup (Sortie)	Rendezvous and Dock Orientation and Pointing	Full Operation	None
Propulsion (Free-Flying RAM)	Ground Test	None	Stationkeeping	Rendezvous and Dock (Station Supported) Dock (Shuttle Supported) Zero-g Resupply (Station Supported) Exchange RCS Elements (Shuttle Supported)	Safing
Comm/Data	Ground Interface and Test Ground Operation	Reduced Data Caution and Warning	Full Data Space Operation	Full Data Space Operation	Voice Checkout
Controls and Displays	Ground Operation	Space Operation	Space Operation	Space Operation	Ground Operation

or stringent requirements usable for only a few payloads. Wide variations in payload requirements place additional demands on the subsystems beyond their basic capability, and can be met more efficiently by employing subsystem add-on capability.

Table 2-3 identifies major payload integration equipment in both categories and relates this equipment to experiment discipline. Equipment installation varies with each discipline or representative payload since it is dependent on payload definition and the characteristics of the payload itself such as sensitivity to operations, pressurized versus unpressurized location, or natural or induced environment.

2.3.5 USER REQUIREMENTS. The basic support capability of RAM payload carriers is determined from an analysis of the common demands of the representative experiment payloads. The cost and development and integration schedules are also considered in establishing the standard or basic support capability of a RAM element or

combination of elements. The net capability to support a given payload is equal to the total capability of the RAM elements plus payload integration equipment minus subsystem support requirements.

Table 2-4 summarizes the net capability of the payload carriers to support the requirements of the user. This table lists the capabilities of RAM elements in their operational mode; i.e., either for individual RAM payload carriers in the case of sortie RAM, free-flying RAM, and RAM payload module attached to the station or as combinations of elements (sortie RAM + RAM pallet, RAM payload module + RSM + RAM pallet, RAM payload module + RSM or sortie RAM). In all cases, the basic RAM capabilities and the payload integration equipment are presented.

2.4 SELECTED RAM ELEMENTS

At the conclusion of Task 4.2/4.3, a set of RAM elements (Figure 2-7) was defined and recommended to NASA for preliminary design. The elements, consisting of a pressurized RAM, an unpressurized RAM pallet, and a pressurized free-flying RAM, satisfied the basic study requirements: Level 1 guidelines, derived requirements from Task 4.1, and the requirements of the interfacing systems. The recommended pressurized RAM had three derivatives; sortie RAM, RAM support module, and RAM payload module of two lengths. The RAM payload module is suitable for use in either the sortie or the station-attached modes. This family of elements permits a variety of options dependent on annual funding level and experiment program requirements. The mounting of external equipment can be accommodated by adding a simple RAM pallet, which provides the sensor-mounting area. The sortie RAM is normally operated by two payload specialists. By introducing the RSM and the RAM payload module, both of which have the same pressurized structural shell as the sortie RAM, the number of payload specialists can be increased. Free-flying RAMs can be interjected into the program as required to satisfy the program requirements and serviced as needed by the shuttle with a sortie RAM. The recommended elements and their required interfaces are summarized in the following sections.

2.4.1 RAM SYSTEM INTERFACES. Interface characteristics are of vital importance to RAM since key features of the RAM payload carrier design are based on the design and capability of the interfacing systems. The RAM mission requires that the payload carrier interface with other program items including the shuttle orbiter, the space station, TDRS, the communications ground network, and the shuttle ground system. There are also interface connections between the RAM elements. A summary of the interface connections for each RAM element, space station, and shuttle combination available for use in the RAM project is presented in Section 3.4.

2.4.1.1 Intersystem Interfaces. The intersystem interfaces were originally defined and documented in Task 4.2/4.3. Prior to the initiation of Task 4.4, the shuttle program vehicles were redefined and the modular space station Phase B study was completed. The completion of the modular space station study had a minor effect on the interface

Table 2-3. Major Payload Integration Equipment Items

	Astronomy	Physics	Earth Observations	Communication/ Navigation	Materials Science	Technology	Life Sciences
INTEGRATION EQUIPMENT	Experiment installation structure Contamination monitor Fine thermal control Radiation protection Contamination protection Gimbals & controls Lint free garments	Experiment installation structure Contamination monitor Radiation protection Gimbals & control Film vault Boom Subsatellite adapter & controls Cryogenic system Lint free garments Effluent control	Experiment installation structure Contamination monitor Contamination protection Gimbals & control Film storage cabinet Booms Cryogenic system	Contamination monitor Contamination protection Gimbals & control Film storage cabinet Booms Subsatellite adapter & controls	Film storage cabinet Effluent control system + gas	Experiment installation structure Film storage cabinet Launch/ recovery adapter Teleoperator or Astronaut maneuvering unit	Experiment installation structure Film storage cabinet
SUBSYSTEM ADD-ON	CCTV Bulkhead Barrel section Pressurizable housing with hinged dome Pressure dome CMG Fixed-head star tracker Strapdown rate-gyro package Precise stability Data recorder Extra data tapes	Airlock Bulkhead Experiment structure (cosmic ray bay) Peak battery	Bulkhead Barrel section Pressure dome Peak battery Data recorder Extra data tape	Airlock Bulkhead Barrel section Pressure dome Peak battery & charger	CCTV Peak battery & charger Data recorder Extra data tape	CCTV Airlock Bulkhead Experiment structure (tank support) Data recorder Extra data tape	CCTV Data recorder Extra data tape 30 day add-on (expendables)

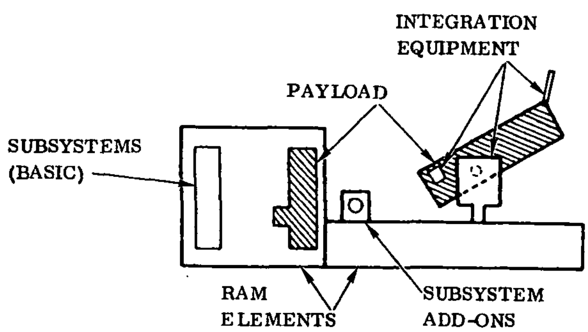


Table 2-4. RAM Payload Support Capabilities

Parameter	Sortie RAM	Sortie RAM + RAM Pallet	RAM Payload Module + RSM	RAM Payload Module + RAM Pallet + RSM	Station-Attached RAM Payload Module	Free-Flying RAM
Basic Payload Capabilities						
1. Payload Equipment Volume (ft^3)	750	Sortie RAM - 750 Pallet - 2500	18-ft RAM Payload Module - 900 32-ft RAM Payload Module - 2000	RAM Payload Module - 900 Pallet - 2500	18-ft RAM Payload Module -900 32-ft RAM Payload Module -2000	920
2. Payload Crew Size/ Manhour per Day	2/21.5	2/21.5	4 to 6/45.5 to 69.5	4 to 6/45.5 to 69.5	4 to 6/40 to 60	2/21.5 (in-orbit servicing)
3. Electrical Power Total, unregulated (±15%)	4.4 kW, 600 kW-hr	Same as sortie RAM	Same as sortie RAM except energy up to 1000 kW-hr	Same as RAM payload module + RSM	3.2 kW	1.3 kW
28 vdc ±5%/115v, 400 Hz	1500W/1250va				1500W/1250 va	500W/500 va
4. Data Acquisition Data Rate	67 Mbps	67 Mbps	67 Mbps	67 Mbps	25 Mbps	1.24 Gbps
Storage (bits per reel/No. of reels)	$6.2 \times 10^{10}/21$	$6.2 \times 10^{10}/21$	$6.2 \times 10^{10}/35$	$6.2 \times 10^{10}/35$	1.0×10^{10}/stored in station	$5.1 \times 10^{10}/1$
5. Control and Display	Payload dedicated C&D console, mission event timers, intercom, caution and warning	Console: same as sortie RAM plus closed circuit TV on manipulator arms to view pallet.	Console in RSM same as for sortie RAM	Same as sortie RAM + pallet.	C&D provided by station RAM has intercom, caution and warning, payload-dedicated C&D	(Console in sortie RAM for in-orbit servicing)
6. Communications (Transmission Capacity)	Shuttle-provided. S-band: 1 Mbps peak Max contact - 3 to 11% of time	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Station provided TDRS: 10 Mbps S-band: 1 Mbps peak Max contact - 3 to 11% of time	TDRS: 10 Mbps digital 10 MHz analog
7. Guidance, Navigation, and Control	Shuttle provided	Shuttle provided	Shuttle provided	Shuttle provided	Station provided	
Pointing acc	±0.5 deg	±0.5 deg	±0.5 deg	±0.5 deg	±0.25 deg	±1 Arc Sec.
Stability	±0.03 deg/Sec	±0.03 deg/Sec	±0.03 deg/Sec	±0.03 deg/Sec	±0.05 deg/Sec	±0.5 Arc Sec.
Position (n. mi)	±1.0	±1.0	±1.0	±1.0	±1.0	0.3 (Via
Velocity (fps)	±10	±10	±10	±10	TBD	2.0 TDRS)
8. Thermal Control* Air temp (°F)/heat rejection (Btu/hr)	80 to 100/0 to 3100	Same as sortie RAM	18 ft: 80 to 120/ 0 to 3700 32 ft: 70 to 115/ 0 to 7500	80 to 120/0 to 3700	18 ft: 70 to 80/ 0 to 2900 32 ft: 85 to 105/ 0 to 6600	
Cold plate temp/ heat rejection (Btu/hr)	75 to 95/0 to 3100	Same as sortie RAM	18 ft: 90 to 105/ 0 to 3700 32 ft: 85 to 95/ 0 to 7500	90 to 105/0 to 3700	18 ft: 65 to 70/ 0 to 2900 32 ft: 85 to 100/ 0 to 6600	60 to 115/0 to 5000*
9. Viewports	Three viewports, 12-inch diameter, located at aft 45 deg conical section provide hemispherical coverage.	One viewport, 12-inch diameter, located at aft 45 deg conical section.	Same as sortie RAM+ pallet.	Same as sortie RAM + pallet.	Same as sortie RAM	None

*Air and cold plate temperature ranges shown are for 3σ worst case orbital conditions and include effects of degraded thermal control surfaces.

Table 2-4. RAM Payload Support Capabilities, Contd

Parameter	Sortie RAM	Sortie RAM + RAM Pallet	RAM Payload Module +RSM	RAM Payload Module + RAM Pallet + RSM	Station-Attached RAM Payload Module	Free-Flying RAM
Basic Capabilities (Contd)						
10. Feedthroughs	Two 8-inch-diameter feed-through ports located at aft 45 deg conical section	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Provided in experiment integration bulkhead per individual payload requirements.
Integration Equipment and Add-on Options						
1. Airlocks No. /diam (ft)/ length (ft)	3/3.5/11 or 1/5.7/6	None	3/3.5/11 or 1/5.7/6	None	3/3.5/11 or 1/5.7/6	None
2. Special Bulkheads	102-inch outer diameter for three 42-inch outer diameter airlocks; 102-inch outer diameter for one 72-inch outer diameter airlock; 102-inch outer diameter sensor mounting	None	Same as sortie RAM	None	Same as sortie RAM	136-inch outer diameter for installation of instruments and/or for pressurizable access
3. Deployment Booms	Three standard booms of lengths 10, 40, and 160 ft	None	Same as for sortie RAM	None	Same as for sortie RAM	None
4. Gimbals	Three 2-axis gimbals installed on deployment booms	Two standard gimbals: 1. Large, 5-axis 2. Small, 5-axis	Same as for sortie RAM	Same as for sortie RAM + pallet.	Same as for sortie RAM	None
5. Fine Thermal Control	None	Two standard shrouds: 1. 76-inch outer diameter x 140 inches long 2. 87-inch outer diameter x 140 inches long + radiator add-ons + thermal interface unit.	None	Same as for sortie RAM + pallet.	Standard thermal control shrouds and thermal interface units + radiator add-ons	Special thermal control shrouds and standard thermal interface units per individual payload requirements + radiator add-ons
6. Guidance, Navigation and Control Pointing Accuracy (arc-sec) Stability (arc-sec)		±1.0 (Add CMGs 10.5 and gimbals)		±1.0 (Add CMGs 10.5 and gimbals)		±1.0 (Add reaction ±0.005 wheels)
7. Peaking Battery	14 kW-hr increments, up to 4 increments	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	90 kW, 22 kW-hr	None

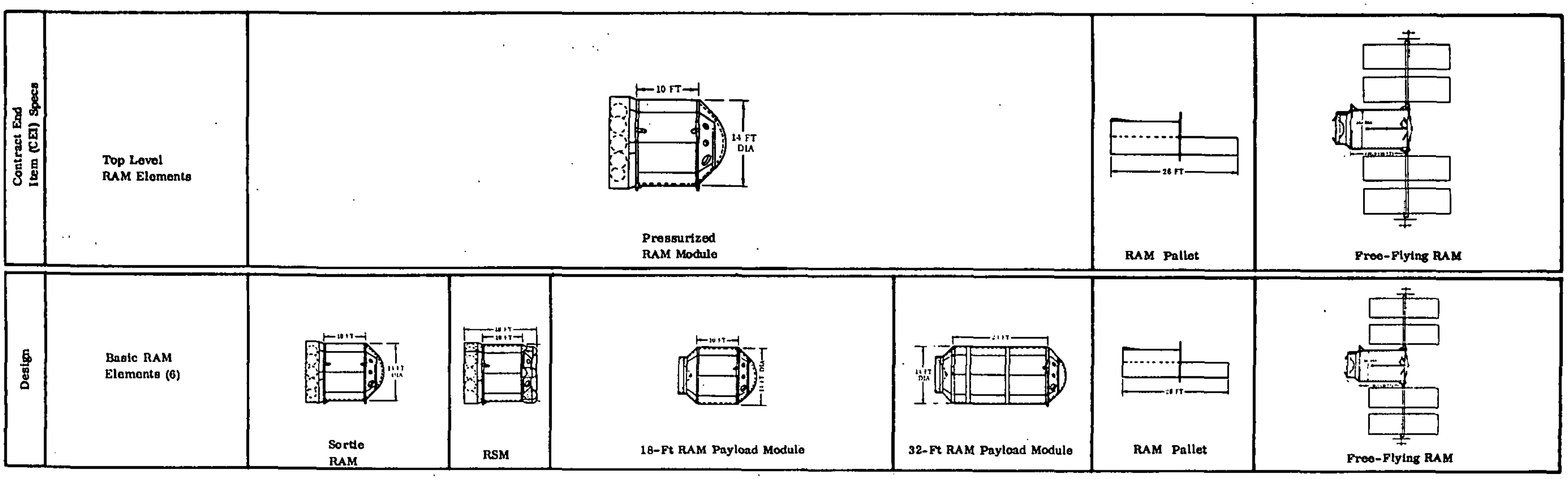


Figure 2-7. RAM Elements

requirements. Redefinition of the shuttle orbiter, however, significantly impacted the RAM payload carrier interface requirements. The other system interfaces (the communications ground network, TDRS, and the launch site ground systems) remained relatively unchanged.

Since the RAM payload carriers are basically self-sufficient in the sortie mode, a minimum physical interface with the shuttle system is maintained. This is consistent with the desire to maintain minimum shuttle refurbishment costs and recycle time. Some of the orbiter capability, however, is used by RAM payload carrier including:

a. RAM crew $\leq$ 2 and RAM crew provisions $\leq$14 mandays.

b. Food and hygiene facilities for RAM crew$\leq$6.

c. Emergency electrical energy$\leq$ 50 kW-hr.

d. RAM payload carrier caution and warning and control of critical subsystems during RAM deployment. This is accomplished at the orbiter mission specialist station.

e. The shuttle's orbital maneuver subsystem tankage and propellant for velocity increments $\leq$1000 fps.

f. The shuttle attitude control propulsion subsystem propellant for velocity increments $\leq$ 120 fps.

g. Voice communications via VHF/TDRS.

h. Telemetry and command via S-band communication link.

A summary definition of the interface requirements for the redefined shuttle orbiter used in Task 4.4 is provided in Section 3.4. Compared to the orbiter definition used during Task 4.2/4.3, major orbiter subsystem changes impacting RAM were in the orbital maneuver system (OMS) and the attitude control propulsion system (ACPS). In the initial orbiter design, the OMS and ACPS propellants were supplied from a centralized storage system, enabling RAM mission planners to trade off orbital altitude versus propellant consumption for vehicle stability and attitude. In the current orbiter (used for preliminary design), the OMS and ACPS subsystems use different propellants and are therefore modularized with no interconnection, thus reducing overall mission flexibility. In addition, the OMS basic design provides a velocity increment of 1000 fps with an add-on kit for the second 1000 fps. The kit is in the cargo bay, occupying the last seven feet of the bay and reducing the availability payload bay length from 60 to 53 feet. The weight of the OMS kit is now chargeable to RAM and therefore reduces the permissible payload weight by a minimum of 2000 pounds for those missions requiring the OMS kit.

In establishing the requirements for commonality of interface connections between the RAM elements, shuttle orbiter, and space station, the following operational factors must be considered.

a. Free-flying RAMs are delivered to orbit by the orbiter and serviced by the sortie RAM, or the space station.

b. RAM payload modules are attached to the RSM, sortie RAM, or space station and, in the latter case, delivered to station by the orbiter.

c. RAM pallets are attached to a sortie RAM payload module.

d. Sortie RAM, RSM, and RAM payload modules have a high degree of commonality to reduce costs.

2.4.1.2 Intrasystem Interfaces. Interfaces between the RAM elements are determined by the following operational and design factors.

a. Sortie RAM provides power, control, data handling, and thermal control for attached RAM pallets.

b. Sortie RAM provides repressurization, atmospheric conditioning, power, control, data handling, and depressurization of free-flying RAMs during shuttle-supported servicing missions.

c. RSM or sortie RAM provides repressurization, atmospheric conditioning, thermal control, power, control, data handling, potable water for experiments, and depressurization of attached RAM payload modules during sortie missions. The RAM payload modules contain additional radiator area for supplemental heat rejection. The thermal control fluids are supplied and controlled from the RSM.

d. RAM payload module transfers power, control, data handling, and thermal control to attached RAM pallet. These services originate in the RSM or sortie RAM when operated in the sortie mission mode.

2.4.2 PRESSURIZED RAM. The primary purpose of the pressurized RAM is to provide an enclosed, protective environment for the application of scientific research. The enclosed environment permits direct involvement by principal investigators or their representatives in a shirtsleeve mode. The modules, singly or in combination, contain the subsystems necessary to maintain the habitable environment and provide direct support to experiment apparatus such as structural mounts; power; thermal control; communications; data management; guidance, navigation, and control; and supplemental facilities such as airlocks for unique experiment requirements. Additionally, the pressurized RAM provides an interface between the payloads and shuttle orbiter. As previously identified, the pressurized RAM includes three adaptations: the sortie RAM, RAM support module, and RAM payload module. These RAM payload carriers are described in Section 3.1.

2.4.3 UNPRESSURIZED RAM (PALLET). The primary purpose of the unpressurized RAM is to provide a mounting surface for large payloads requiring direct exposure to space and real-time manned participation with no maintenance of the external experiment during on-orbit operation. The principal user of the RAM pallet is the astronomy dis-

cipline and the Technology experiments involving propellant transfer and the maneuvering work platform. RAM pallets are applicable to the sortie missions only, operating attached to a pressurized RAM that provides the subsystem service provisions for the RAM pallet. A detailed description of the unpressurized RAM is provided in Section 3.2.

2.4.4 PRESSURIZABLE (FREE-FLYING) RAM. The primary purpose of the pressurizable RAM is to provide a long-duration stable platform with a contamination-free environment beyond the capabilities of the shuttle or space station. Free-flying RAMs operate on-orbit in an unmanned and unpressurized mode. On-orbit manned maintenance and servicing is provided by one of two methods. For the shuttle-supported free-flying missions, a shuttle with a sortie RAM deployed from the cargo bay can periodically rendezvous with the free-flying RAM; in the space-station-supported free-flying missions, the free-flying RAM rendezvous and docks to the space station. A detailed description of the pressurizable RAM is provided in Section 3.3.

2.5 RAM EXPERIMENT PLANS

RAM experiment plans have been used throughout the RAM Phase B study as a basis for establishing RAM experiment payloads and identifying RAM project requirements. A baseline REP, consistent with a NASA-supplied program schedule, was used early in the study to identify experiment payloads, representative of all mission modes and varying in experiment complexity.

During subsequent tasks, additional RAM experiment plans were defined to represent a number of RAM program funding possibilities. Financially constrained programs spanning the range of peak funding from \$50M/yr to \$250M/yr were emphasized. These programs employed various mixes of RAM elements and used various combinations of the representative RAM experiment payloads. Collectively, these programs provided insight into what could be accomplished in the area of space experimentation at various funding levels. They also provided a basis for selecting a set of RAM elements that could be used effectively in a space experimentation program while remaining relatively insensitive to the specific program parameters (e.g., funding level or payload mix).

One RAM experiment plan, financially constrained to \$150M/yr, was selected as a basis for further RAM project planning. Although this plan is not unique — other \$150M/yr programs are possible — it was selected as a reasonable basis for estimating the number and type of RAM elements and the phased development of these elements as required to support a typical program. This plan is summarized in Figure 2-8. The left side of the figure describes the activity for each discipline in each mission mode; the right side shows the funding required and a count of the RAM elements and shuttle flights required by the program. This plan provides a reasonably balanced program with sortie missions in all experiment disciplines, laboratories in a station-attached mode as early as 1985, and a free-flying RAM program that begins in 1980 with an LST service

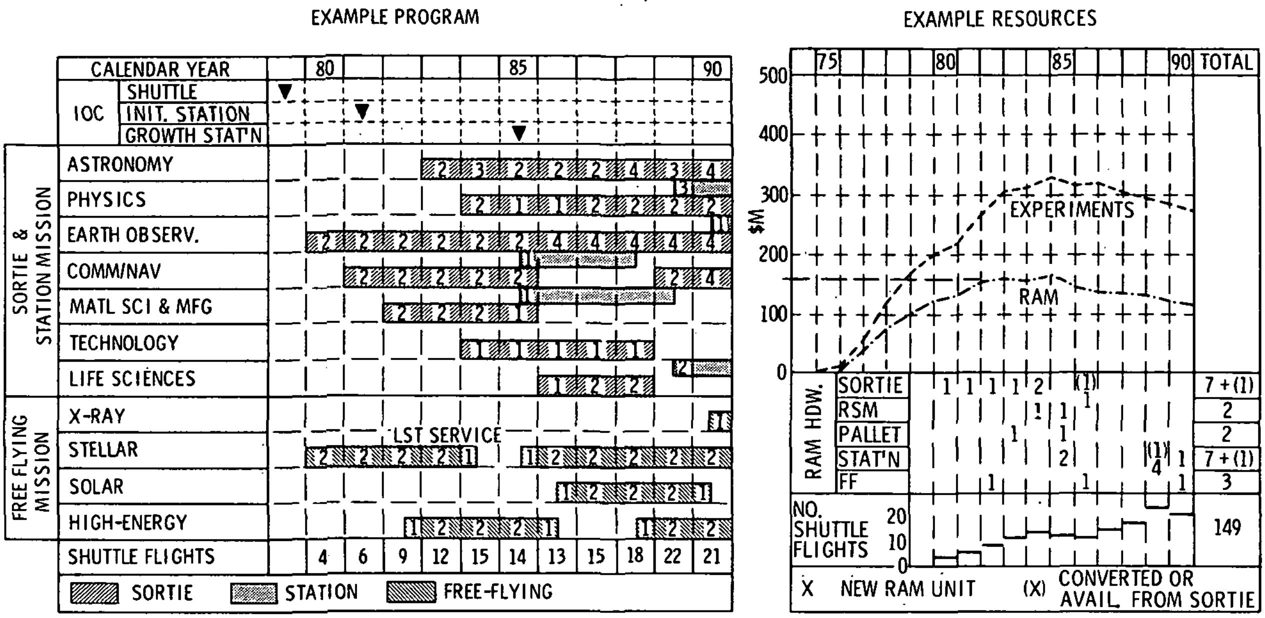


Figure 2-8. RAM Experiment Plan ($150M/yr Constraint)

mission followed by the sequenced introduction of the remaining free-flying RAM payloads beginning in 1982. An RSM is introduced in 1984 to provide for a four to six man operation in several experiment disciplines. The rapid drop in RAM project funding in later program years is a consequence of defining experiment payload activity only through 1990. In reality, the development and procurement of additional RAM elements and the integration of new RAM experiment payloads for flights beyond 1990 would (if they were defined) require additional RAM project funding beyond that shown for 1986-on.

The RAM elements needed to support the program are shown in Figure 2-9. Assignment of these elements is predicated on the assignment of specific experiment payloads in the plan, but a wide variation in payload assignments could be made without significant change to the RAM element requirements shown. RAM element assignments are usually made by dedicating a RAM element to a particular payload, refurbishing that element as required, and reconfiguring the element to a new payload in the same discipline. For sortie flights, when the flights associated with one discipline are completed, the RAM element may be reconfigured to accept a new payload discipline, assigned to free-flying RAM service, or modified to a new type of element (e.g., sortie RAM to RAM payload module) as required by the program.

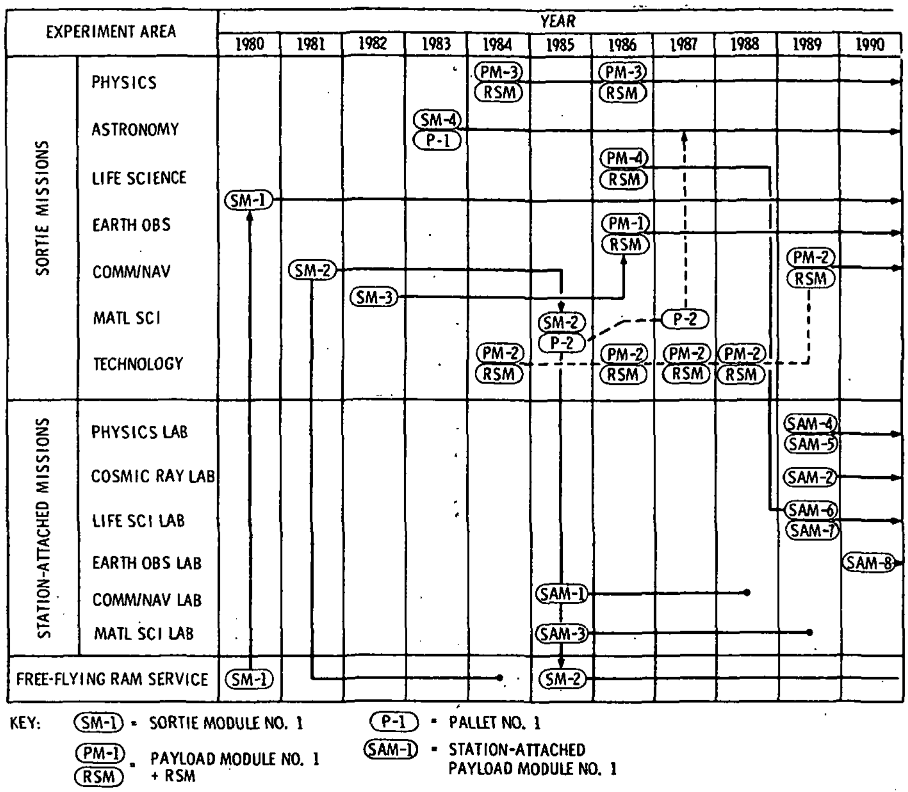


Figure 2-9. RAM Hardware Used in $150M/yr-Constraint Experiment Plan

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 3

CONFIGURATION DEFINITION

Prepared by
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SECTION 3

CONFIGURATION DEFINITION

The RAM project study concluded with a preliminary design definition of a family of RAM elements that were fully responsive to the study requirements. The RAM elements consist of a pressurized RAM, an unpressurized (pallet) RAM, and a free-flying RAM. The basic pressurized RAM element, from which the other pressurized RAM elements evolved, is the sortie RAM. The addition of a simple structural pallet to the sortie RAM provides an additional sensor mounting area to accommodate externally mounted payloads.

The sortie RAM is basically a self-sufficient system with minimum shuttle interface to minimize shuttle refurbishments costs and recycle time. Some of the orbiter capability, however, is used by the sortie RAM. This includes the crew seats and restraints during boost and entry, sleeping accommodations, food and hygiene facilities for two payload crewmen, and communication and electrical power resources. Sortie RAMs can be converted into RAM support modules (RSMs) and RAM payload modules. The RSM has the same primary structure, subsystems, and control and display console as the sortie RAM. Seats and bunks are provided in the space normally occupied by the experiment equipment. The RAM payload module is required only to provide advanced capability and is applicable to both sortie and station-attached missions. In the sortie mode, it is always attached to RSM or sortie RAM.

Free-flying RAMs provide a stable platform with a contamination-free environment for payloads for periods up to five years. They are serviced at periodic intervals by a shuttle orbiter vehicle with a sortie RAM attached or by the space station.

The orthogonal coordinate axes and reference planes used by the RAM project are similar to those of the space shuttle system, as shown in Figure 3-1. The only difference between the systems is the location of the longitudinal datum plane, which for the RAM project originates at the shuttle-to-RAM-payload-carrier interface plane.

Descriptions of the RAM family of payload carriers, (pressurized, pressurizable, and unpressurized) resulting from the preliminary design effort are described in this section.

3.1 PRESSURIZED RAM

The pressurized RAM element has three adaptations: the sortie RAM, RAM support module (RSM), and RAM payload module. One of the primary objectives in the preliminary design of RAM elements was to maintain a high degree of commonality,

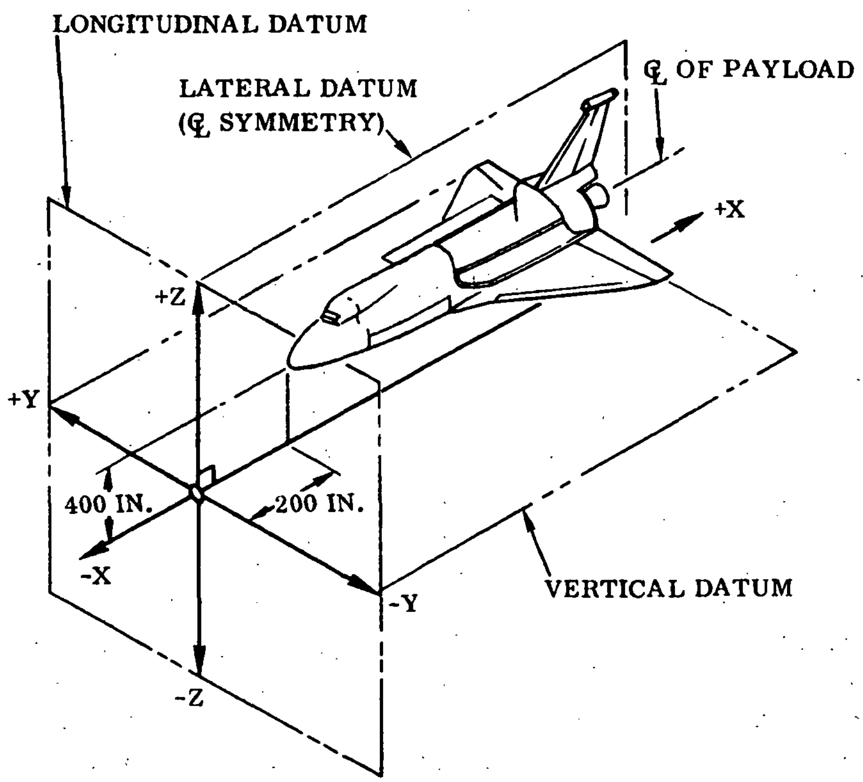


Figure 3-1. RAM/Shuttle Orbiter Coordinate Axis System Relationship

thereby minimizing initial costs. To achieve this objective, commonality of subsystems and assemblies was maintained among pressurized RAM derivatives and with other space programs. Structural commonality was achieved by using the basic module primary structure shown in Figure 3-2 for the sortie RAM, RSM, and RAM payload module. This structure consists of a 160-inch-deep primary end (kick) ring at each end. A 45-degree conic section is attached at each end of the cylinder, truncated by a 102-inch-diameter bolting flange normal to the cylinder centerline. The forward end of each module has a bolted-on and sealed docking structural assembly. This structural assembly interfaces with the shuttle orbiter (RSM or sortie RAM in the case of RAM payload modules) and contains a

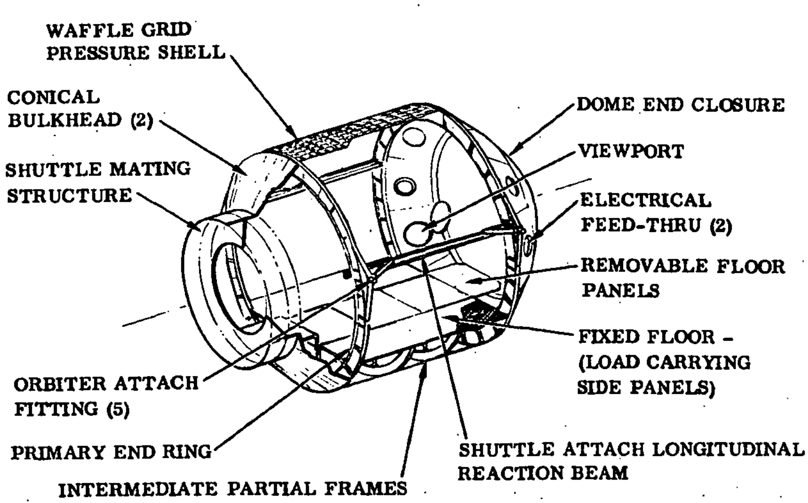


Figure 3-2. Pressurized RAM Basic Structure

pressure door for isolation of the specific module. The closure on the aft end of the pressurized module is configured for payload usage. These configurations all use the primary structure components shown in Table 3-1. Secondary structure and other subsystems also have common usage between the various derivatives of the pressurized RAM.

3.1.1 SORTIE RAM

3.1.1.1 Configuration. The sortie RAM is based on a crew size of 2 + 2 (i.e., two orbiter crewmen consisting of commander and pilot and two RAM crewmen). Since the other pressurized RAMs (RSM and RAM payload modules) evolve from this element, its design reflects the requirements of the other pressurized modules. Major features of the sortie RAM are:

a. A 14-foot-diameter pressure shell approximately 18 feet in overall length.

b. Subsystems that provide essential resources for the crew and experiment payload.

c. An interior arrangement consisting of a control and display console for management of subsystems and selected experiments and provisions for easy installation and removal of experiment equipment peculiar to each payload.

d. Provisions for interfaces with the orbiter and shuttle ground support facilities. The interface with the orbiter allows use of the shuttle resources and permits crew movement between the sortie RAM and orbiter.

e. A removable 102-inch-diameter aft domed bulkhead, which can be replaced by special bulkheads capable of supporting internal viewing instruments and large external experiment sensors. The removable bulkhead may be replaced by a docking assembly for servicing of the free-flying RAM.

f. A 160-inch-diameter aft flanged ring, which provides for the attachement of external sensors or an unpressurized (pallet) RAM.

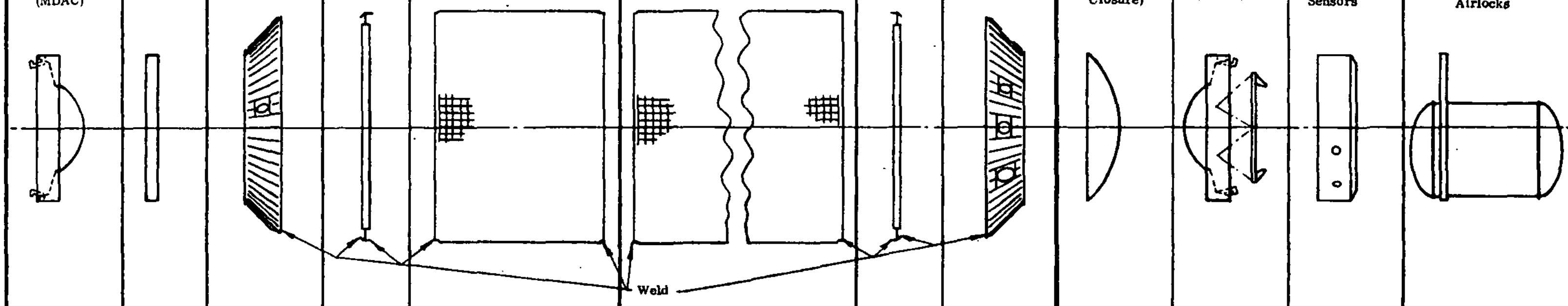
The general arrangement of the sortie RAM is presented in Figure 3-3; pertinent characteristics are listed in Table 3-2.

The sortie RAM shell is sized to accommodate the subsystems and early experiments. The integrated control and display console is located at the forward end, with the payload aft. The payload area allows for subsequent conversion to the RSM, and removal of the control and display console permits conversion to a RAM payload module. The internal arrangement is designed for ease of crew movement and access to equipment.

External Arrangement

The module primary structure consists of a 160-inch-diameter waffle skin constant-section cylinder 120 inches long with an 8-inch-deep frame at each end. A 45-degree conic section is attached at each end of the cylinder and truncated by a 102-inch-diameter bolting flange normal to cylinder centerline. The forward conical section

Table 3-1. Primary Structure Components



PRESSURIZED RAM	STRUCTURAL COMPONENTS								Applicable to Designated Payload			
	Interface Adapter Assy. (MDAC)	8-Inch Extension	Forward Conical Section	Kick-Ring	10-Ft. Constant Section	24-Ft. Constant Section	Kick-Ring	Aft Conical Section	Domed End (Basic Closure)	Interface Adapter and Docking Assembly (MDAC)	Experiment Peculiar Bulkhead, Sensors	Experiment Peculiar Bulkhead, Airlocks
	UTILIZATION											
Sortie RAM	● Structure ● Seal ● Latches ● Hatch	Nominal Config.	With Feed-thrus: ●Pwr, Ctl, Mon. ●H_2O ●GO_2, GN_2 ●Atms Vent	Nominal Config.	Nominal Config.	—	Nominal Config.	With: ●3 Viewports ●4 Feed-thrus	Astronomy Mat. Science	See Free-Flyer Servicer	Earth Obs. Comm/Nav.	Comm/Nav. Physics
RSM	● Structure ● Seal ● Latches ● Hatch	Nominal Config.	With Feed-thrus: ●Pwr, Ctl, Mon. ●H_2O ●GO_2, GN_2 ●Atms Vent	Nominal Config.	Nominal Config.	—	Nominal Config.	With: * ● 1 Feed-thru	—	● Structure ● Seal ● Latches	—	—
18-Ft. Payload Module - Sortie	● Structure ● Seal ● Latches ● Hatch	—	Without Feed-thrus	Nominal Config.	Nominal Config.	—	Nominal Config.	With: ●3 Viewports ●4 Feed-thrus	Astronomy Mat. Science Tech.	—	Earth Obs. Comm/Nav.	Com/Nav Tech. Physics
18-Ft. Payload Module - Station Attached	● Structure ● Seal ● Latches ● Hatch	Nominal Config.	With Feed-thrus: ●Pwr, Ctl, Mon. ●H_2O	Nominal Config.	Nominal Config.	—	Nominal Config.	With: ●3 Viewports ●4 Feed-thrus	—	● Structure ● Seal ● Latches ● Hatch	—	Comm/Nav.
32-Ft. Payload Module - Sortie	● Structure ● Seal ● Latches ● Hatch	—	Without Feed-thrus	Nominal Config.	—	Nominal Config.	Nominal Config.	With: ●3 Viewports ●4 Feed-thrus	Life Science Mat. Science	—	—	Physics
32-Ft. Payload Module - Station Attached	● Structure ● Seal ● Latches ● Hatch	Nominal Config.	With Feed-thrus: ●Pwr, Ctl, Mon. ●H_2O	Nominal Config.	—	Nominal Config.	Nominal Config.	With: ●3 Viewports ●4 Feed-thrus	Life Science Mat. Science	—	Earth Obs.	Physics
Free-Flyer Servicer	Sortie RAM	Sortie RAM	Sortie RAM	Sortie RAM	Sortie RAM	—	Sortie RAM	Sortie RAM	—	● Structure ● Seal ● Latches ● Hatch ● Docking Sys.	—	—

*The RSM does not require the (3) viewports nor (3) of the (4) feed-thrus. However, it is not adversely affected by having these hull penetrations and can be a direct conversion from a Sortie RAM in this regard.

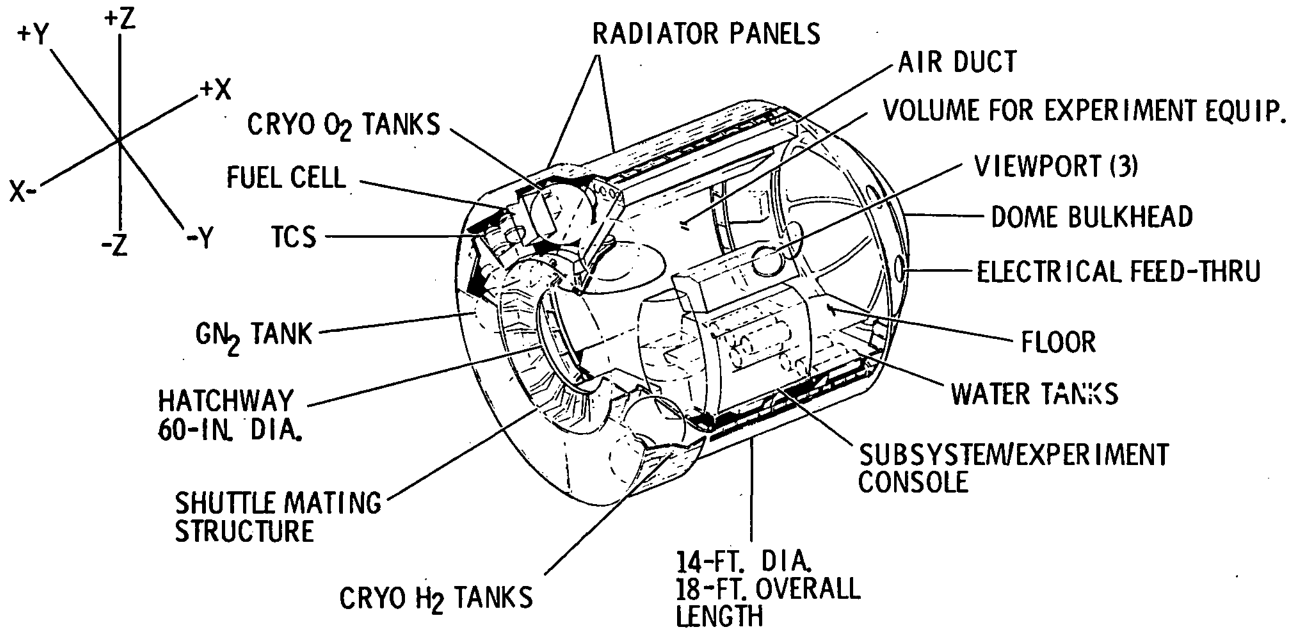


Figure 3-3. Sortie RAM General Arrangement

is mated to an interface adapter assembly that physically interfaces with the orbiter. This adapter assembly is basically a space station docking assembly without the docking frame, attenuator/actuators, hydraulic/air power systems, and associated controls. The conical section at the aft end has a closure dome mating at the 102-inch-diameter attaching ring in the basic configuration. Replacing the closure dome with a payload-peculiar bulkhead provides added capability for special payload accommodation. These payload-peculiar bulkheads are designed to accommodate the sensors and other payload equipment as shown in Figure 3-4. The equipment bay is wrapped around the forward conical section (Figure 3-3). This space is enclosed by a peripheral 3-foot-long radiator extending aft from the orbiter interface plane, six access panels on the equipment bay and the cylindrical section. Due to the selection of storage tanks from space shuttle Phase B studies for commonality, the diameter across the radiator panels is 15 feet, which is the maximum envelope allowed. Located within the equipment bay, are two cryogenic oxygen tanks, three cryogenic hydrogen tanks, two nitrogen gas tanks, one fuel cell, fuel cell ancillary equipment, thermal control essential components, and a ground disconnect panel for those ground services required up until T-5 seconds before liftoff.

The forward conical transition section is pierced by four feedthroughs for fuel cell cabling and all forward external control and monitor circuits, water plumbing, gaseous oxygen and nitrogen, and the cabin atmosphere relief and vent valve.

External to the constant-diameter section of the pressure hull and the aft conical section is protective insulation and an integrated radiator/meteoroid bumper. The radiator/meteoroid bumper consists of eight similar panels covering the entire periphery.

Table 3-2. Sortie RAM Characteristics

Parameter	Basic Configuration	With Experiment Bulkhead (not including experiment)	Free-Flying RAM Servicing Configuration
Overall Length	225.0 in. (18.75 ft)	228.0 in. (40.33 ft)	216.0 in. (18.0 ft) (interf. to interf.)
Constant Section Side Wall Length	120.0 in. (10.0 ft)	120.0 in. (10.0 ft)	120.0 in. (10.0 ft)
Internal Diameter, Pressure Shell	160.0 in. (13.33 ft)	160.0 in. (13.33 ft)	160.0 in. (13.33 ft)
External Diameter, Radiator/Meteoroid Bumper	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)
Maximum Diameter (Fwd Radiator)	180.0 in. (15.0 ft)	180.0 in. (15.0 ft)	180.0 in. (15.0 ft)
Internal Volume	1950 ft^3	1980 ft^3	1890 ft^3
Floor Arrangement	Longitudinal	Longitudinal	Longitudinal
Support Fittings Orbiter Attach (Quantity)	5	5 without pallet 3 with pallet	5
Hatches	1 at 60.0 in. dia.	1 at 60.0 in. dia.	2 at 60.0 in. dia.
Viewports	3 at 12.0 in. dia aft cone 1 at 6.0 in. dia., hatch	3 at 12.0 in. dia., aft cone 1 at 6.0 in.dia., hatch	3 at 12.0 in. dia., aft cone 2 at 6.0 in.dia., 2 hatches
Crew Complement (orbiter + payload)	2+2	2+2	2+2
Mission Duration	7 Days Nominal	7 Days Nominal	7 Days Nominal
Electrical Power System			
Power Source	1-7 kW Cont Duty Fuel Cell	1-7 kW Cont Duty Fuel Cell	1-7 kW Cont Duty Fuel Cell
LO_2 Tanks, 33.0 O.D.	2-Shared with life support	2-Shared with life support	2-Shared with life support
LH_2 Tanks, 33.0 O.D.	3	3	3
Distribution Voltage	28 vdc	28 vdc	28 vdc
Maximum Energy Capacity	1034 kW-hr	1034 kW-hr	1034 kW-hr
Power Peaking Batteries (Add-on)*	500 AH Ag-Zn	—	—
EC/LSS (Independent System)			
Atmosphere Pressure	14.7 psia; pp O_2 = 3.1 psia	14.7 psia; pp O_2 = 3.1 psia	14.7 psia; pp O_2 = 3.1 psia
pp CO_2	5mm Hg	5mm Hg	5mm Hg
Atmosphere Temperature	Selectable 65° to 85°F	Selectable 65° to 85°F	Selectable 65° to 85°F
Waste Water Tanks, 3100 $in.^3$	1	1	1
H_2O By-Product Storage Tanks, 3100 $in.^3$	7	7	7
N_2 Tanks 25.3 O.D; 3100 psia	2 on -X Cone	2 on -X Cone	2 on -X Cone; 3 on +X Cone
CO_2 Removal	LiOH	LiOH	LiOH
TCS (Two Loop, Radiator Bypass System)			
External Loop	Freon 21	Freon 21	Freon 21
Internal Loop	H_2O	H_2O	H_2O
Equipment Cooling	Cold Plate and Air	Cold Plate and Air	Cold Plate and Air
Radiator Area	531 ft^2	531 ft^2	531 ft^2
Ascent/Descent Cooling & Transient Peaks	Sublimator & Therm. Stor.	Sublimator & Therm. Stor.	Sublimator & Therm. Stor.
Cooling Capacity, Radiator	16,100 Btu/hr minimum	16.100 Btu/hr minimum	16,100 Btu/hr minimum
Prelaunch & Post Landing	GSE	GSE	GSE
Communications	Shuttle Provided Hardline to Orbiter VHF/TDRS Voice Low Rate Data & CMD S-band -1 Mbps data	Shuttle Provided Hardline to Orbiter VHF/TDRS Voice Low Rate Data & CMD S-band -1 Mbps data	Shuttle Provided Hardline to Orbiter VHF/TDRS Voice Low Rate Data & CMD S-band -1 Mbps data
Data Management System			
Data Handling	Tape Recording 50 Mbps – 1.3×10^{12} Bits/ Mission	Tape Recording 50 Mbps – 1.3×10^{12} Bits/ Mission	Tape Recording 50 Mbps – 1.3×10^{12} Bits/ Mission
Processing	Central Computer	Central Computer	Central Computer
Acquisition & Command Distribution	Full Multiplex	Full Multiplex	Full Multiplex
Checkout, Fault Isolation	Integrated Into DMS	Integrated Into DMS	Integrated Into DMS
Controls and Displays Console	2-Man Integrated Console	2-Man Integrated Console	2-Man Integrated Console
Habitability			
IVA Suits, Umbilicals	2 Suits, 4 Umbilicals	2 Suits, 4 Umbilicals	2 Suits, 4 Umbilicals
IVA Stations	1	1	1
Weight, Dry (Without Payload and Expenables)	10,216 lb	10,689 lb	10,728 lb

* Can be added to any configuration. Only demand is in basic configuration.

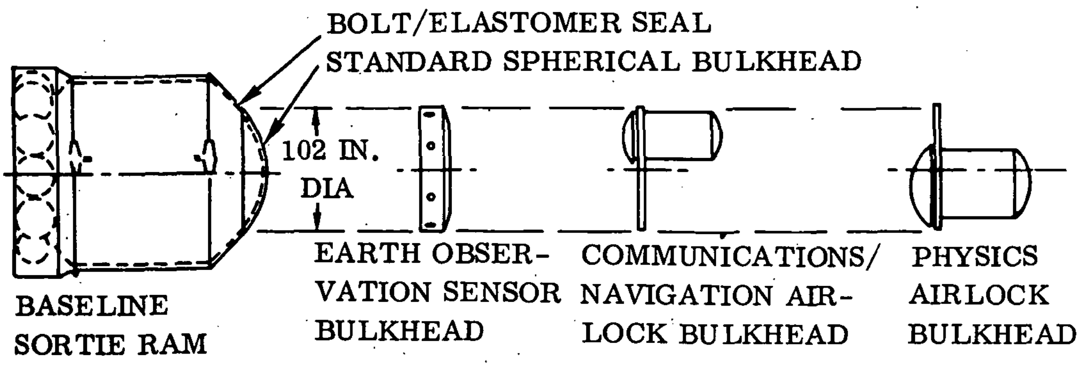


Figure 3-4. Experiment-Peculiar 102-inch Pressure Bulkheads

Panels at each end of the constant-diameter section permit access to a structural mounting ring at the juncture of the constant-diameter section with the conical sections. The structural mounting rings (Figure 3-5) are extensions of the end frame. These rings (one forward and one aft) are the primary mounting points for subsystem tanks and components. The forward ring is the primary structural base for three orbiter attachment fittings. By removing the access panels, two hoist fittings on the top side may be bolted onto the ring and two fittings on the lower side of the ring may be added for ground support and air shipment.

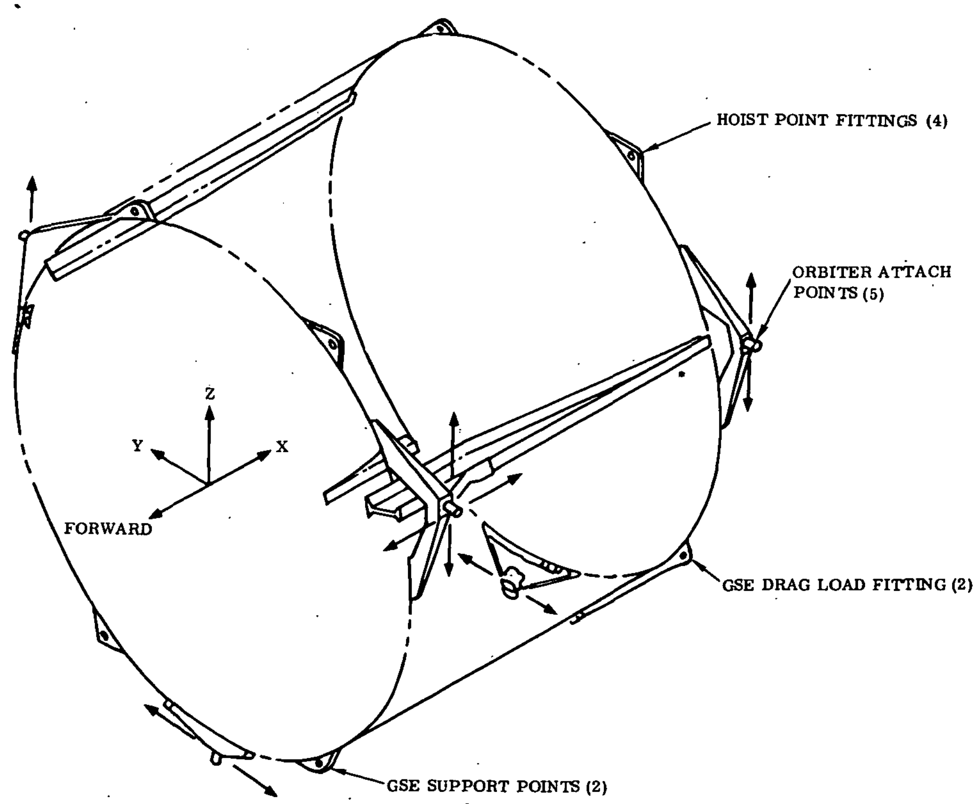


Figure 3-5. Sortie RAM Attachment Fittings

The aft ring is the primary structural base for two orbiter attachment fittings, two hoist fittings topside, and two GSE drag load fittings on the lower side. It is also used for mounting certain equipment apparatus. The hoist and ground/shipping fittings are not flight hardware.

The aft conical section is at the experiment-active end of the module. Only the access panels are affected when the sortie RAM is modified to support different payloads. This section is penetrated in seven places, as shown in Figure 3-6. Three 12-inch-diameter clear viewports are located 120 degrees apart. Two subsystem feedthroughs are located on the Y axes and each provides electrical power and lines for control and data circuits. These two feedthroughs supply the experiment equipment located on the RAM pallet or experiment bulkhead. Two feedthroughs are provided at 30 degrees up from the Y-Y horizontal plane on each side of the module for experimenter use for obtaining data to support their experiment.

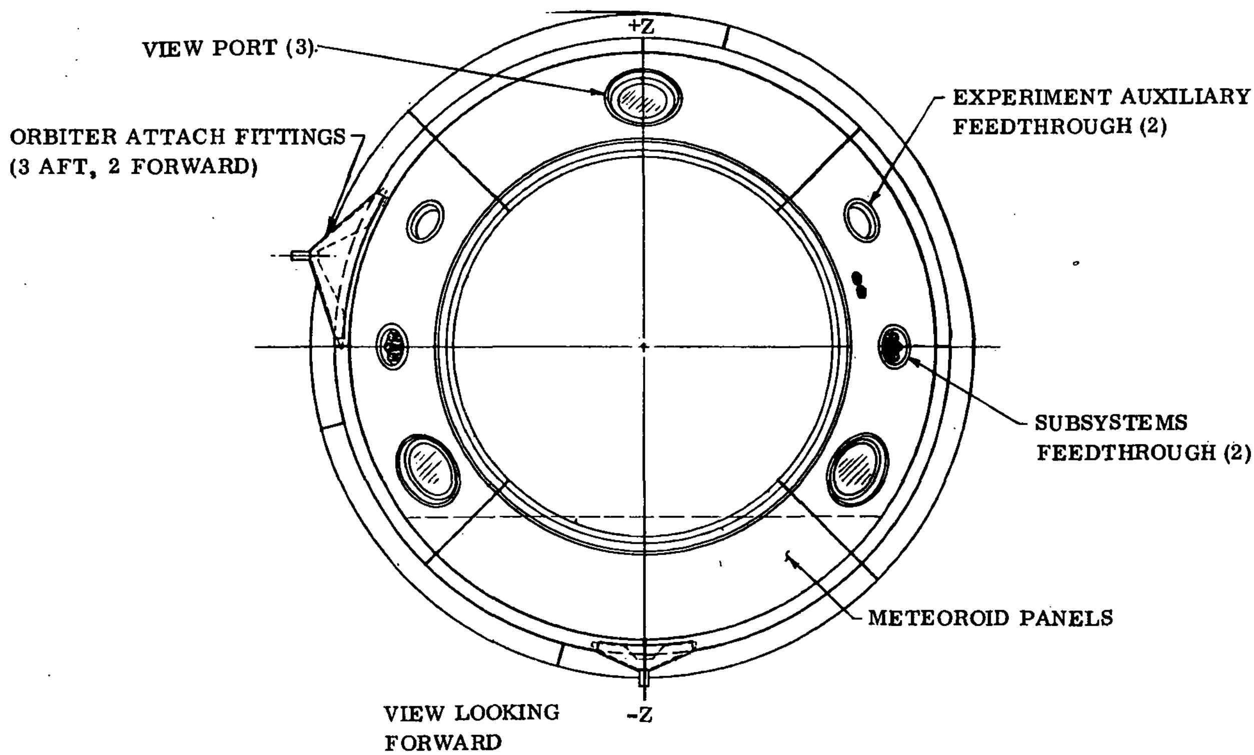


Figure 3-6. Sortie RAM Aft Conical Section

Internal Arrangement

The internal architectural features of the sortie RAM are styled by the horizontal floor arrangement. The floor location is 46.00 inches below the vehicle horizontal centerline. Utility troughs, which form the structural edge members of a ceiling, are used for certain utilities and as a base for attaching overhead framework for equipment installations.

The interior floor is the primary and direct structural interface with most of the internal subsystems and experiment equipment. Figure 3-7 shows a plan view of the floor layout.

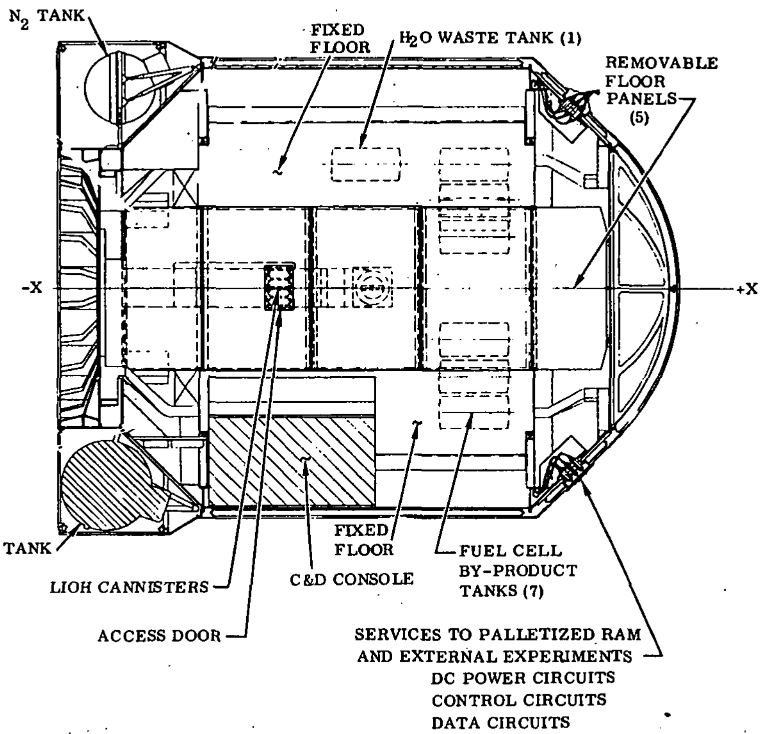


Figure 3-7. Sortie RAM Floor Arrangement

The floor consists of a fixed section running longitudinally along each wall, with five removable panels through the center that may be removed or replaced with gridded foot-restraint panels for on-orbit operations.

The fixed portion of the floor and two J-section partial frames become the major support structure for the subsystems and experiment equipment. The greater portion of the internal subsystems is installed below the floor, preserving the greatest amount of clear volume for experiment apparatus installations.

The EC/LS subsystem and ducting influences the internal arrangement. The active components are located under the floor, with ducting routed forward then around the +Y side of the cylindrical section using the interface adapter assembly extension as a portion of the duct (Figure 3-8). This duct exits at the top of the EC/LS area, follows the transition cone to the cylindrical section, then goes aft along the +Z side of the hull constant section and terminates at the aft structural ring. This routing was established to obtain adequate air distribution to the bunk areas for the RSM configuration while still meeting sortie RAM requirements. For the sortie RAM used for free-flying RAM servicing, this duct is continued down the 45-degree transition cone to pass through the aft docking interface assembly.

The major equipment item (exclusive of experiment payloads) is the control and display console located on the left-hand side at the extreme forward end of the constant section. Forward of this console (in the forward cone area) is a control panel containing the IVA/face mask station, atmosphere regulation and control components, thermal regulation components, water management components, cabin relief and dump valving, and the fuel cell controller. Located above the console are components of the communication and data system.

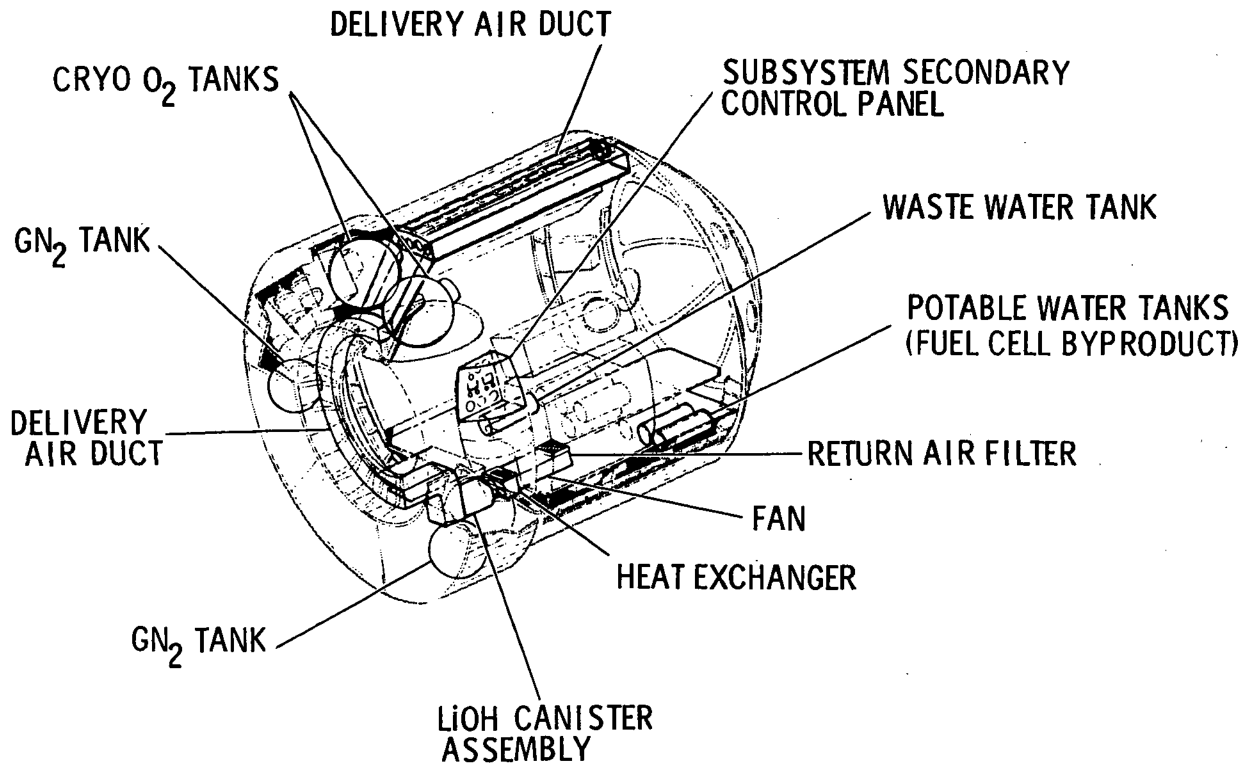
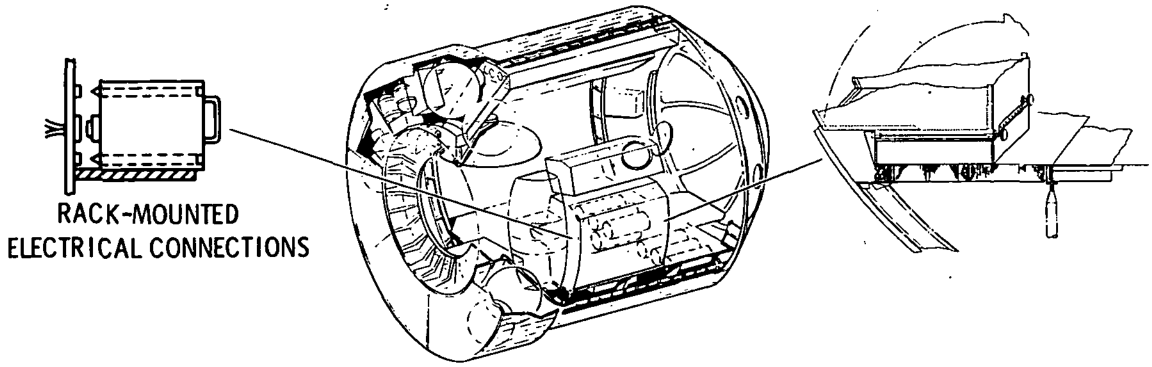


Figure 3-8. Sortie RAM EC/LS Subsystem

Experiment equipment and payload-integration equipment are located in the aft and right side of the sortie RAM. Internal mounting of this equipment is by racks attached to the floor or panels attached to the overhead structure (Figure 3-9). The equipment racks and/or payload display console are mounted on four-inch-high channel supports installed longitudinally on the RAM outboard floor. They are attached by bolts into threaded inserts in the floor. These inserts are installed in the floor for the different length channels required for various payloads, permitting rapid removal and replacement of equipment support channels for refurbishment or maintenance. The equipment racks are hinged on the channel supports. With the equipment hinged inboard, the harnesses, flexible tubing, or other utilities may be disconnected. Temperature control for the equipment in the consoles and racks is integrated into the thermal control subsystem, with the thermal load equally divided between the water loop cooling and the air-cooled system.

A 60-inch-diameter hatch is located at the forward interface structure and opens inward, swinging approximately 90 degrees toward the +Z side. Deployment concepts using a manipulator makes this hatch a requirement for retaining pressure during transition. A deployment concept of 90-degree rotation using a flexible tunnel and not requiring the breaking of interface connections does not require this hatch except as a means of isolating the sortie RAM if it is damaged or if depressurization is required.



- SHIRTSLEEVE ENVIRONMENT
- SELF-MONITORING SUPPORT SUBSYSTEMS
- STORAGE VOLUME
- CONVENIENT ACCESS TO EXPERIMENT EQUIPMENT
- EXTERNAL VIEWING – DIRECT OR TV
- WORK STATION RESTRAINTS
- POWER SUPPLY 28 VDC & 115/200 VAC 400 Hz
- STANDARD RACKS & EQUIPMENT MOUNTING PROVISIONS
- DATA TO GROUND THROUGH ORBITER UP TO IMBPS
- INTEGRATED AND/OR DEDICATED CONTROL & DISPLAY CONSOLE
- INTERCHANGEABLE CLOSURE BULKHEAD
- COLD PLATE AND/OR FORCED AIR COOLING

Figure 3-9. Sortie RAM Experiment Accommodation Provisions

The electrical power subsystem (EPS) provides two power sources, primary and essential:

a. The 7-kW fuel cell is the primary source, with power distributed by the main bus to support all subsystem and experiment loads.

b. If the primary system fails, the orbiter will provide power to operate the essential components of the EC/LS subsystem, lights, communication, and status display. This power is provided to the sortie RAM through two separate cables that penetrate the sortie RAM forward bulkhead and connect to wireways leading to Essential Bus A, under the floor on the left-hand side, and (separately) to Essential Bus B under the floor on the right-hand side. The essential buses are physically isolated to the maximum extent possible.

Other major components of the EPS are located under the floor, on and behind the secondary control panel, on the control console, and internally throughout the module as required. The power/signal distribution system comprises a series of wireways that conduct and protect the wiring to the point of use.

The sortie RAM thermal control subsystem (TCS) is a dual-loop system using water as the heat transfer fluid within habitable compartments. The water loop interfaces with a freon heat-transfer fluid through an interloop heat exchanger. The freon loop is located outside the habitable compartment and transfers heat to the space radiators

for rejection to space. A second freon loop is provided for redundancy. A water sublimator and thermal storage element are provided for additional TCS capability during ascent and entry phases and for use when excessive heat loads are generated during orbital operations.

Maximum use is made of the orbiter to provide for two payload crewmen. Work positions and restraints are provided in the sortie RAM for two men, and stowage for two IVA suits and four umbilicals is provided just above the floor on the right-hand side.

Free-Flying RAM Servicing Configuration

The sortie RAM performs a service function to the free-flying RAMs. This necessitates a replacement of the aft bulkhead with a docking adapter structure incorporating an androgynous docking mechanism with square frame. To provide pressurization to the free-flying RAM, three additional nitrogen tanks are added at the aft conical transition section on the -Z side of the module. These three tanks are also common to the RSM installation. The three tanks are manifolded into an existing external line, which is routed forward into the two-tank nitrogen system before entering the feedthrough. The existing oxygen system is adequate for the free-flying mission and is unchanged. Oxygen and nitrogen are plumbed internally through the utilities trough to the repressurization control valves at the aft bulkhead.

Sortie RAM Capabilities

While the sortie RAM provides significant capability in all scientific disciplines, there are limitations relative to the accomplishment of experiment. These limitations are:

a. Number of Payload Crewmen. A significant quantity of additional data could be obtained on some missions if the number of payload crewmen was increased from two to four or six. Since the orbiter, as defined for this study, could accommodate only two of the payload crew during exit and entry, RAM would have to incorporate provisions for housing the other two to four payload crewmen.

b. Volume. To provide increased capability, additional volume is required to satisfy the requirements of some of the defined payloads. This can be accomplished through the use of the RAM payload module.

c. Traffic Rate. Each sortie RAM incorporates a full complement of subsystems. Between missions, the essential maintenance and checkout can easily be accomplished in two weeks. To change payloads from one discipline to another, however, requires approximately three months. For high traffic rates, there is a definite economic advantage in the use of separate modules for the payload and the subsystems, permitting a single subsystem module (sortie RAM) to be used with several RAM payload modules on sequential missions.

The sortie RAM can evolve into two further derivatives, a RAM support module (RSM) and a RAM payload module.

3.1.1.2 Structure. The basic structure (Figure 3-10) consists of 160-inch-diameter cylindrical section 120 inches long sandwiched between two 45-degree conical bulkheads. The forward end has a barrel section 102 inches in diameter and 8 inches long attached to the conical bulkhead and to the docking adapter. The aft end has a spherical closure bolted to the conical bulkhead.

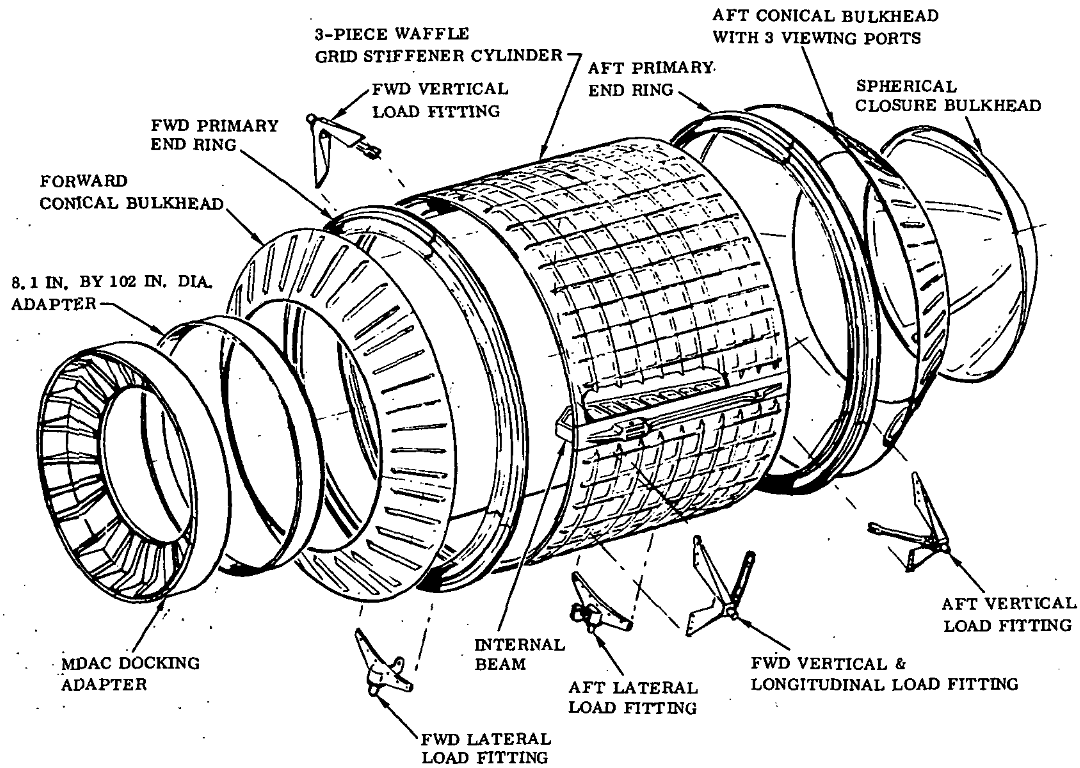


Figure 3-10. Sortie RAM Basic Structure

Mating Structure/Docking Adapter

The docking adapter carried throughout this study is the design developed for the modular space station and identified by the MDAC Drawing 1B80190. It is an integrally machined adapter section made from a 2219-T852 Al-alloy ring forging 102 inches in diameter and 15 inches long. It houses the androgynous docking system, if required, which used a square docking frame. The docking frame is manipulated with eight hydraulic/air attenuator actuators and has a latching system with provision for 12 active latches on each side of the interface. It incorporates a 98-inch-diameter inflatable seal at the interface. It also has a nominally 60-inch-diameter hatch on the centerline. The docking adapter can be attached to the conical bulkhead at the 102-inch diameter using a bolt-ring flange and static seal.

102.0-Inch-Diameter Adapter

This adapter is made from a one-piece roll-ring forging of 2219-T852 aluminum alloy as an integrally machined thick-wall cylinder with end bolt-circle flanges.

Cylindrical Sidewalls

The cylindrical section consists of three panels 120 inches long formed to the 160-inch-inside diameter. It has two primary end rings 8 inches deep and with I cross-sections. Two longitudinal I beams are welded into the cylindrical section at a location approximately 15 degrees above the horizontal centerline. The beam at the -Y, the left side looking forward, is 12 inches deep. The other beam is 3 inches deep.

The three segments of the cylinder span between the two beams and from these beams to the bottom centerline. The cylindrical panels are made with integrally machined waffle-grid stiffeners. The type of waffle selected is a 5-inch 20-degree square grid with the stiffeners on the outside of the module. The grid is 1 inch deep, the stiffeners are 0.050 inch thick, and the skin thickness is 0.070 inch. The cylindrical panels, the primary rings, and the horizontal beams are made from 2219 aluminum alloy.

Conical Bulkhead

The 45-degree conical bulkhead provides the transition between the 160-inch-diameter cylindrical sidewall and the docking adapter. The bulkheads are made from three segments welded together at a longitudinal seam, each segment consisting of a 0.055-inch skin with longitudinal and integrally machined blade stiffeners 1 inch high and 0.10 inch wide. Each segment also has an integrally machined frame for the windows.

The attachment to the cylinder is at a welded joint at the kick ring (primary end ring). The 102-inch-diameter interface is a bolt ring welded to the cone. These bulkheads are also made from 2219 aluminum alloy.

Closure Bulkhead

This bulkhead forms a simple membrane closure for the aft end of the sortie RAM. The membrane is a portion of a sphere and is welded to a ring bolted to the 102-inch-diameter interface of the aft conical bulkhead. The membrane is 0.055 inch thick 2219-T851 aluminum alloy; the ring is 2219-T852 alloy.

Secondary Structure

The secondary structure comprises the floors, the utility tunnels and ceiling components, and the external equipment support structure. The floors are horizontal (i.e., parallel to the X-Y axis) and are made from two fixed sections running along each wall with five removable 60-inch-wide panels through the center. The fixed sections are 3-inch-deep aluminum honeycomb, and the removable panels are 1-inch-deep aluminum honeycomb.

The 3-inch-deep side panels are 31 inches wide by 124 inches long, extending between the outer edge of the circumferential ring caps. The edges of the panels are finished by bonding 3-inch-deep channel and zee sections between the face sheets. The zee sections are toward the center and pressure wall (Y plane) and the channel sections are at the ends. The zee at the outer edge is supported by a drag angle secured to the pressure wall and to the circumferential rings on each end.

Support along the inboard edge of the panels consists of four vertical tubular struts extending to the circumferential rings and two intermediate partial frames. The partial frames are J-sections attached to the pressure wall and run circumferentially under the floor between the floor intersections with the pressure shell.

Spanning the 60 inches between the side floor panels are four intercostals equally spaced (40 inches on center) between the centers of the circumferential frames. The intercostals are hat sections, the flanges of which are secured to the protruding leg of the side panels.

The center section panels are of aluminum honeycomb sandwich construction. The edges are closed out by either a 1-inch-deep channel or a zee section. Zee sections are along the forward and aft edges (the legs securing to the intercostals), and the channel sections are adjacent to the side panels. These panels are removable and are supported by the intercostals only. The aft panel attaches along its forward edge to the aft intercostal and is clipped at two places to the 102-inch-diameter aft structural ring.

The forward removable panel extends from the forward intercostal to the hatch bulkhead. This panel is 6 inches above the remainder of the floor to clear the EC/LS ducting. The forward right cover is also cut around the semi-circular duct. Additional side edge members reinforce this panel. Attachment is to the forward intercostal and the hatch bulkhead.

A common set of secondary structural components comprises the ceiling structure inside the module. The sortie RAM and the RSM each have two utility tunnels 44 inches from the Z centerline and 36 inches from the X centerline plus a single tunnel on the Z centerline that is 24 inches wide and 70 inches from the X centerline. The RSM also has two sleeping compartments and personal equipment storage areas. The area used by the sleep compartments is used for equipment mounting on the sortie RAM and the RAM payload modules.

Typical secondary structure includes that used to mount external subsystem equipment such as the N_2 bottles for the EC/LS subsystem (which are mounted to the forward primary end ring) and the mating ring on the docking adapter on both the sortie RAM and the RSMs. Each of these bottles is individually truss mounted. Other subsystem equipment such as the water sublimator, thermal storage elements, and freon control valves are platform mounted and attached to the end rings and the docking adapter ring.

Environment Protection

The radiator/meteoroid bumper is made froma sandwich of 0.016-inch outer and 0.010-inch inner aluminum skins bonded to a high-temperature polyurethane foam core. The radiator/bumper panels cover the cylindrical portion of the module and are split into sets of eight 45-degree sections. Each panel contains 15 fluid passages installed longitudinally; four of these are integral with an I-shaped extruded stiffener and the others in a D-shaped extrusion bonded within the sandwich. The fluid passages are connected at the ends of the panels in a radial direction. These connections are made through a valving system that controls the fluid flow in the eight panels. The panels are about 5.4 by 9 feet and are attached to the sidewall at both ends through hinge fittings that allow the panel to expand or contract under temperature variations.

A similar system is used for the auxiliary radiator over the subsystem tanks on the forward end of the module.

Environmental protection of the conical bulkhead and the closure dome uses the same sandwich construction as the cylindrical section, but without the radiator tubes.

Access covers are made in eight sections and are attached to the cylindrical section at the kick rings with slip joints. These covers may be removed to expose the radiator manifold and the hoist fitting attachments. Other access panels on the cylindrical section are removed to expose the ground handling and transportation fittings.

The entire surface area of the module with the exception of the docking interface is covered with 45 layers of SuperFloc insulation. The insulation is supported on fiberglass clips and attached to the bulkheads and the cylindrical sidewall by non-metallic fasteners.

RAM/Orbiter Attachment Fittings

The attachment fitting concept selected for RAMs is a five-point reaction statically determinate system. The five fittings on the orbiter were assumed to be of ball or trunion mount form located 93 inches from the Y-Z centerline and 25 inches above the Y-Y axis. The fittings on the sortie RAM are three tripod types (only one of which reacts the longitudinal load) and two simple A-frames that only react lateral loads.

This design uses two tripod fittings at the forward +Y and -Y and one at the rear -Y location. Two A-frame fittings are located at the forward and aft -Z positions. A beam is used to accept the local moment induced by the longitudinal load and to react this load at the two end rings. The outer flange of this I-shaped beam is welded into the cylindrical side wall, forming a splice joint for the machined panels. The beam is 12 inches deep at the load application location and tapers to 8 inches deep at the forward end and 4 inches at the aft end. An integral blade is machined on the surface of the outer flange of the beam and is used to attach the machined link that forms the third leg of the tripod fitting. Each of the tripod fittings is made from a machined steel

A-frame and a machined link as the third leg. This link is attached to the A-frame through a simple clevis and to the upstanding blade of the beam through a knuckle or double clevis attachment. There is also a small beam placed at the +Y location. This beam gives symmetry to the cylindrical structure and provides a structural tie for the orbiter fittings, which will induce small loads in the longitudinal direction.

Crew Mobility/Stability Aids

Crew mobility/stability aids are required to assist the crewmen in performing operations and maintenance tasks on sortie RAM subsystems and experiments. These tasks include such things as hatch operation, experiment setup, reconfiguration of the sortie RAM for various mission phases, wall and equipment access, and crew coordinated activities. These crew aids can be fixed or portable and will include hand rails, foot restraints, and tether attach brackets. The specific location of these aids will be determined after a detailed crew analysis to indicate heavy traffic or task loading areas. Representative hand hold, hand rail and leg rail mobility and stability aids are shown in Figure 3-11.

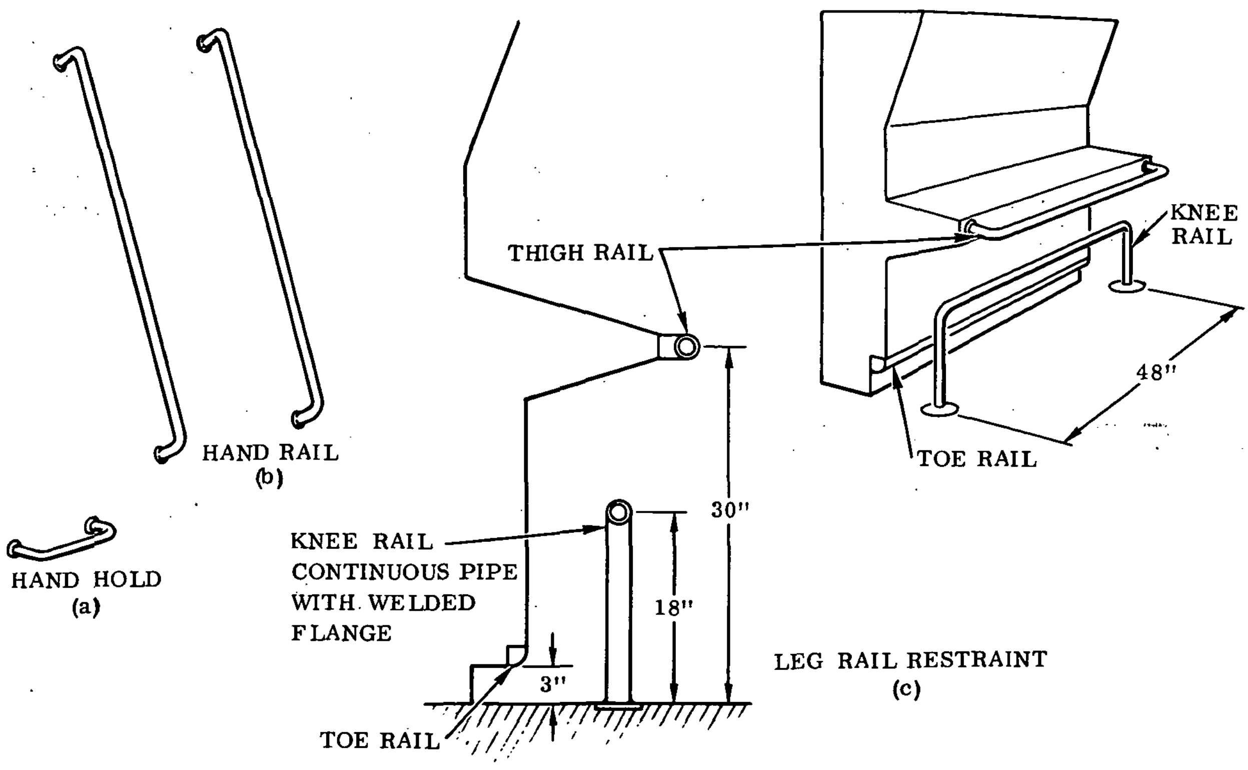


Figure 3-11. Representative Hand Holds, Hand Rails, and Leg Rails

The general arrangement and orientation of sortie RAM interior equipment indicate that heavy traffic or task loading occurs at the various work stations. The primary restraint is an open metal triangular grid network in the 1-g floor position, providing

capability for a compatible shoe restraint attachment of discreet locations throughout the floor area. The Astrogrid floor and the companion Astrogrid shoe restraint are shown in Figure 3-12. The grid floor is located in the center 60 inches of the module. This floor will replace sections of the 1-inch honeycomb panel.

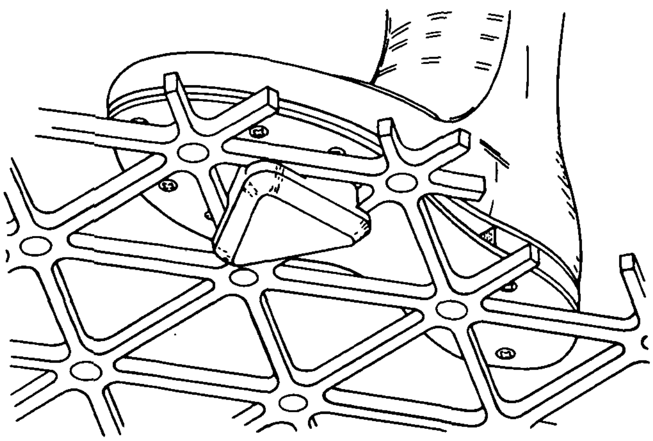


Figure 3-12. Astrogrid Floor and Shoe Restraint

Hand holds and rails may be attached to equipment mounting structure or directly to the cylindrical sidewalls or bulkheads. The forces imposed by crewmen using these retraints are in the low hundreds of pounds and pose no significant structural problems. The locations of these restraints are not critical to the structure; the waffle-stiffened sidewall and the longitudinally stiffened conical bulkhead can accept these low loads at any location.

3.1.1.3 Environmental Control/Life Support (EC/LS) Subsystem. The EC/LS subsystem provides the functions shown in Figure 3-13 for two RAM payload crewmen. The concept selected to provide the functions specified in Figure 3-13 is illustrated in the subsystem schematic shown in Figure 3-14 and described in the following paragraphs.

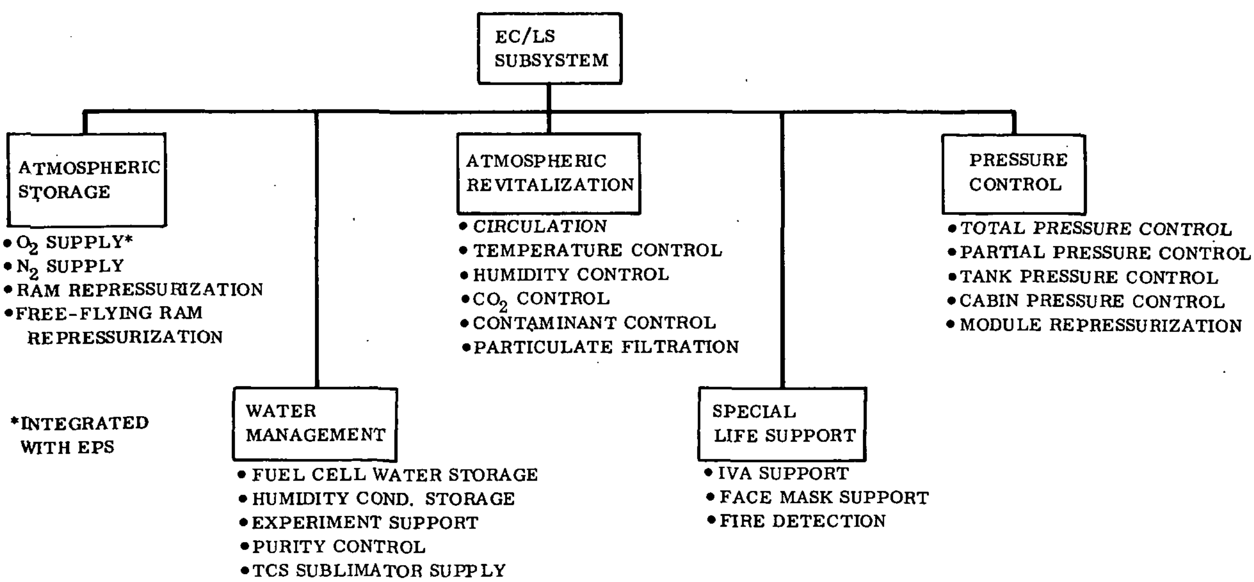


Figure 3-13. Major EC/LS Subsystem Assemblies

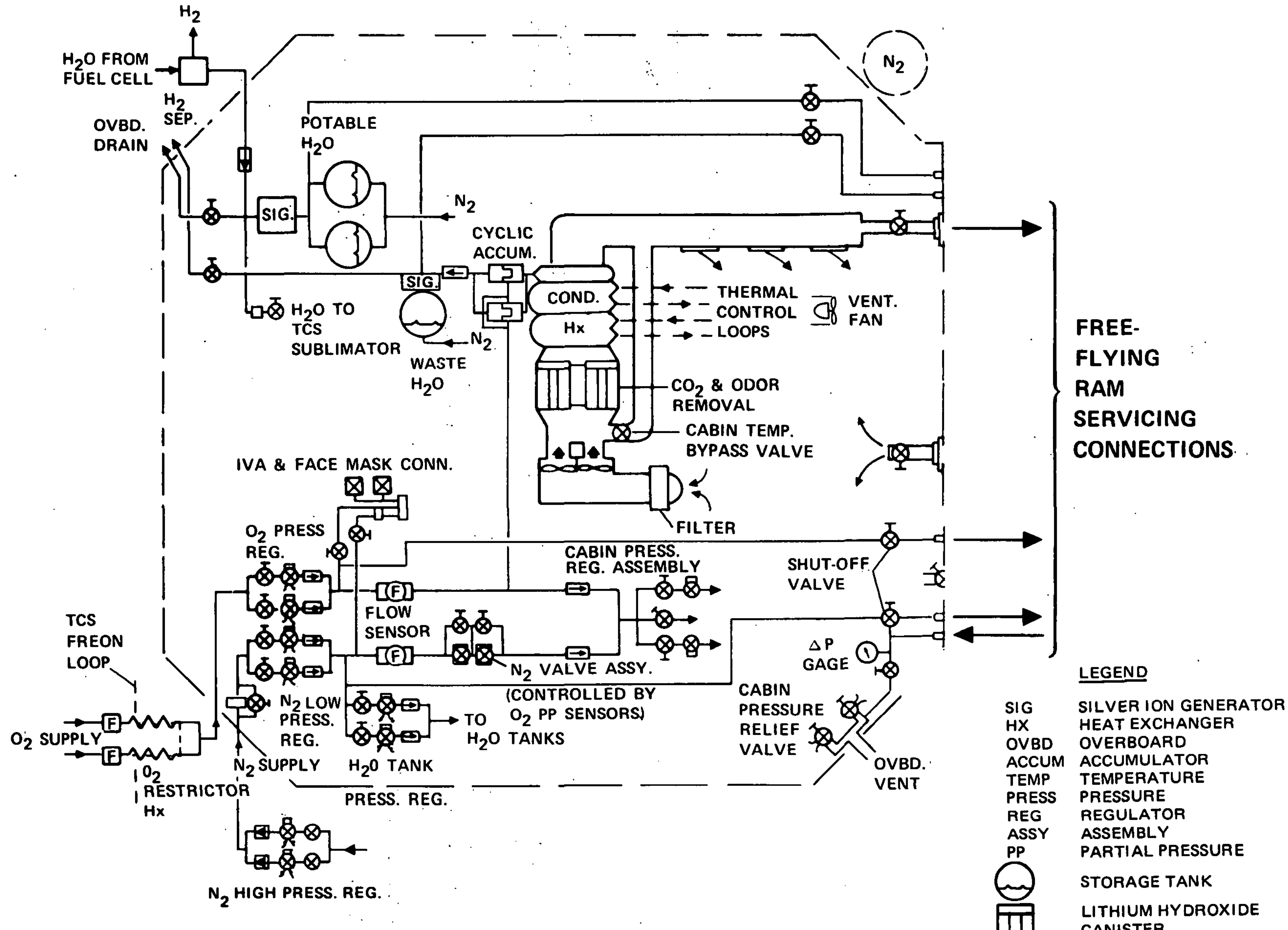


Figure 3-14. Sortie RAM EC/LS Subsystem Schematic

Gaseous Storage Assembly

The gaseous storage assembly consists of the tankage to store nitrogen for module repressurization and leakage. Oxygen storage is integrated with the EPS reactant storage. Each nitrogen tank is 25.3 inches in diameter, weighs 92 pounds, is made of titanium, and can store 60.5 pounds of nitrogen at 3100 psia.

Atmosphere Revitalization Assembly

The atmosphere revitalization assembly circulates cabin atmosphere through various processing units that remove particulate matter and debris, odor, carbon dioxide, water vapor, and heat energy to maintain the atmosphere composition and temperature within specified limits. Composition of the atmosphere is maintained in conjunction with the atmosphere pressure control assembly.

A filter and debris trap is provided to remove particulate matter in the atmosphere and is replaced when the pressure drop indicates a loaded filter. Downstream of the filter, two fans in parallel, each with check valves, circulate the atmosphere through the assembly. Only one fan operates at a time. Lithium hydroxide is used for carbon dioxide removal and activated charcoal for odor and trace gas removal. Each lithium hydroxide canister is sized for a two manday capacity and is designed to be alternately replaced. A condensing heat exchanger provides humidity control. The condensate is collected in cyclic accumulators and pumped to the waste water storage tanks.

The revitalized cabin atmosphere flows through the return duct network, which distributes the air to provide ventilation. To meet the 20-to-50-fpm ventilation requirements, portable ventilation fans are provided at various locations within the module.

The air passing through the condensing heat exchanger is controlled by a bypass to maintain the cabin temperature at a selected value between 65 and 85°F.

Pressure Control Assembly

The pressure control assembly maintains the pressurized volume at 14.7 psia, supplies gaseous oxygen and nitrogen for repressurization and for emergency use, and supplies oxygen gas to the cyclic accumulators and nitrogen gas to the water storage tanks. The sortie RAM contains provisions for supplying and controlling the atmosphere in the free flying RAM during on-orbit servicing.

Cabin atmosphere is maintained at 14.7 psia by controlling the oxygen partial pressure between 3.0 and 3.4 psia and supplying nitrogen gas to make up the balance to achieve the selected cabin pressure. The partial pressure control opens when the oxygen partial pressure is 3.4 psia or above, permitting nitrogen to flow to the cabin pressure regulator until a total cabin pressure of 14.7 psia is reached. When the oxygen partial pressure drops to 3.1 psia, the partial pressure control closes to permit only oxygen to flow into the cabin.

Repressurization, if required, is accomplished by the cabin pressure regulator assembly, which is manually activated by opening the shutoff valves. Positive and negative pressure relief is provided.

Water Management Assembly

The water management assembly provides for sortie RAM water needs, prevents bacteria buildup in the water system, provides storage of fuel-cell-generated water and condensate from humidity removal unit(s), and supplies water for the sublimator in the thermal control subsystem. Water generated by the fuel cell flows through a hydrogen gas separator and a silver ion resin bed to keep it in sterile condition for storage.

Special Life Support Assembly

The special life support assembly is composed of two subassemblies that provide the emergency functions of fire detection and IVA support.

Fire detection is accomplished by a condensate nuclei counter in each module located in the heat exchanger duct system. Since all materials emit large amounts of particles when materials are approaching ignition temperatures, incipient fire hazards are detected by an increased particle count.

Connections for two IVA umbilicals are required. Support is limited to purge flow of oxygen to IVA suits in the event of contingency depressurized or contaminated cabin operations. Oxygen flow is activated manually.

3.1.1.4 <u>Electrical Power.</u> The electrical power subsystem (EPS) provides electrical energy and the associated conditioning and distribution for sortie RAM subsystems and integrated experiment payloads. It provides a capacity based on average and peak power demands of the sortie RAM subsystems and the payload experiment for a specified mission duration and delivers power of a type and quality consistent with the load requirements.

Power Generation

The primary power source is a single fuel cell of the type and capacity under development for the shuttle program. While fuel cell characteristics are contingent upon the shuttle fuel cell development program, the present design calls for 7 kW average power output and a peaking capability of 10 kW for 0.1 hour. The fuel cell output voltage will be 24 to 32 volts, with a minimum operational life design goal of 2000 hours. Fuel cell power is used throughout the sortie RAM mission from liftoff to touchdown. For contingency purposes, there are redundant paths available for power from the shuttle.

Fuel cell purging is required. This occurs approximately once a day, with each purge lasting about five minutes. The quantity of fuel purged is negligible (<0.5 percent)

assuming a fuel cell reactant purity of 99.995 percent by volume for the oxygen reactant. Hydrogen reactant purity of 99.95 percent results in <0.1 pound H_2 purging for 1000 kW-hr.

Fuel-cell water product disposal/storage is a function of the EC/LS subsystem; approximately 0.85 pound of water is produced for each kW-hr of energy generated. Fuel-cell waste heat removal and temperature control are the responsibility of the thermal control subsystem. Waste heat rejection rates for the fuel cell vary with power plant design. Two fuel cell designs are under evaluation for the shuttle program: the electrolyte capillary matrix type (Pratt and Whitney) and the solid polymer electrolyte (General Electric). Typical heat rejection requirements as a function of power level are shown in Figure 3-15.

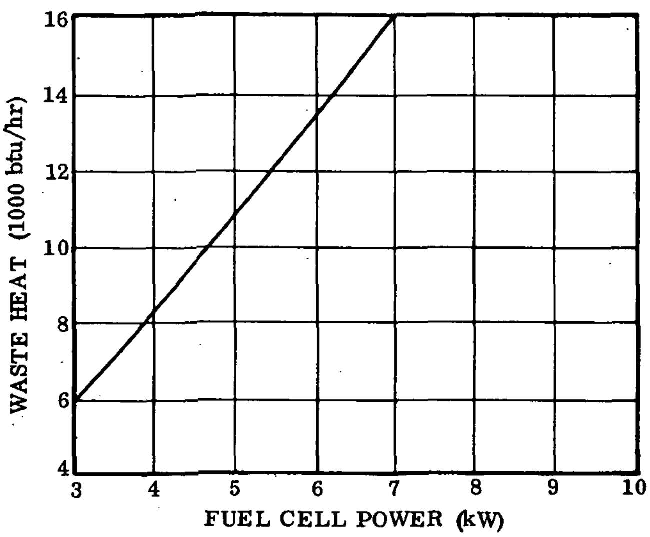


Figure 3-15. Fuel Cell Waste Heat

Reactants are stored in cryogenic tanks of a common design with the shuttle. Two cryogenic oxygen tanks and three cryogenic hydrogen tanks are included to provide a total energy capacity of 1034 kW-hr. EC/LS requirements for oxygen consumption (i.e., metabolic, leakage, repressurization, and IVA contingency) are also provided by the EPS cryogenic oxygen tanks.

Distribution, Conditioning and Control

The distribution concept employs spacecraft-proven technology of 28 vdc and 115 v/200 vac, 400 Hz distribution. Circuit protection and switching design is based on space shuttle technology and uses solid-state power controllers for loads up to ten amperes. For larger loads, hybrid power controllers are used. These units use solid-state elements for control and protection and electromechanical elements for power switching.

The EPS provides three independent power channels (Figure 3-16): a main bus and two essential (emergency) buses. The main bus powers all normal operations including an experiment bus, and the essential buses satisfy the requirement to sustain two failures. The electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contractors. The two essential buses are powered from the shuttle. Provisions are included to interface with either an attached RAM pallet or a free-flying RAM while maintaining the capability to sustain two failures for all elements.

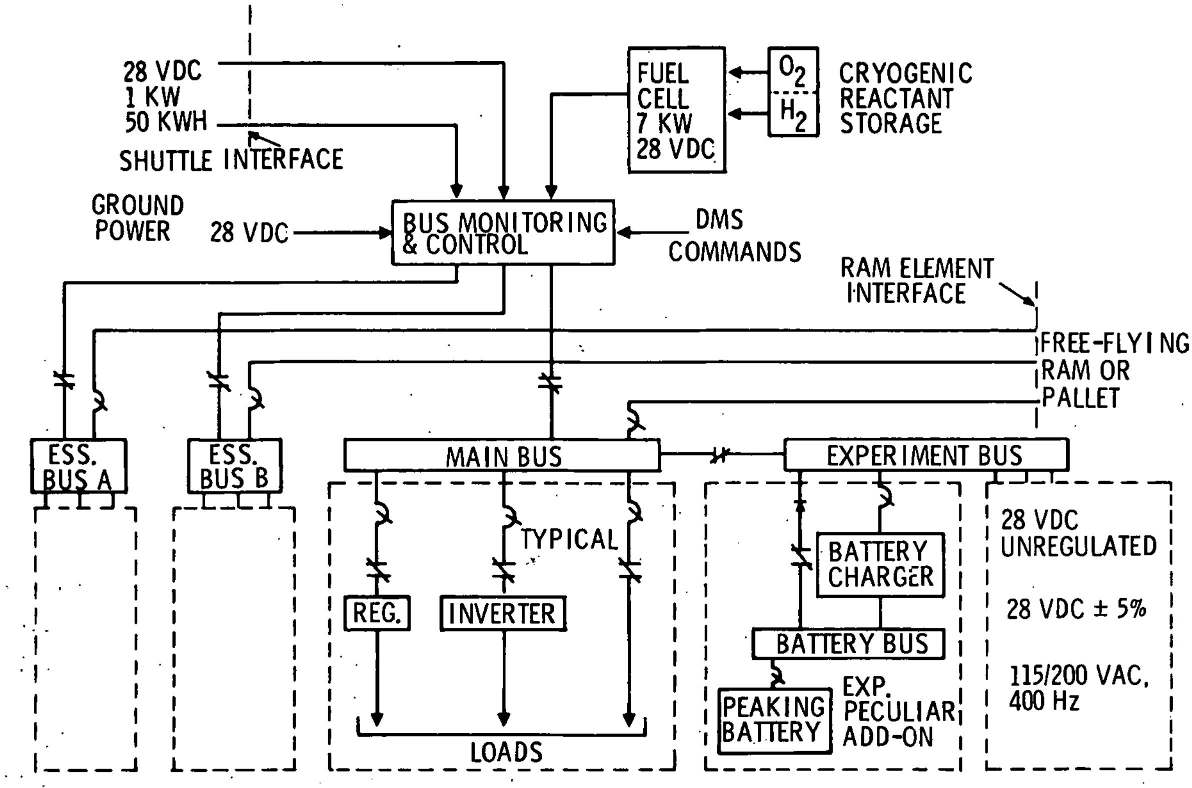


Figure 3-16. Electrical Power Subsystem Schematic

Operational constraints of the wiring and distribution assembly require provisions for the highest-powered reference payload. Add-on provisions are made for auxiliary wiring and installed with the experiment to support higher power requirements.

A generally centralized power conditioning concept is used because it was demonstrated to be more cost effective and require less weight and volume. Conditioning consists of dc voltage regulation and dc-to-ac conversion. Local power conditioning with the load equipment is assumed for the nonstandard power characteristics. The larger conditioning equipment is either flight qualified or flight proven. The 1500 W regulator is a Skylab design and the 1250 va inverter is based on an Apollo design.

Lighting

General area illumination is provided by fluorescent lights, with spot or high-intensity lighting by incandescent lights. Emergency lighting uses independent circuits with independent fixtures in each compartment.

In work areas, the general area lighting is arranged so that lights may be dimmed to conserve energy when activity is reduced for extended periods. A further consideration is changing requirements in work or experiment areas. When work is shifted from one area to another, lights are dimmed in the first area and turned up to full brilliance in the second. Utility outlets are provided for portable lights and other tools.

Auxiliary Power Generation

Electrical power levels above the capability of primary power generation ability (7kW) are required for eight experiment payloads. To meet these requirements, auxiliary energy sources are incorporated into the EPS design as experiment-peculiar kits consisting of 500 amp-hour silver-zinc (Ag-Zn) batteries. Ag-Zn batteries were chosen over nickel-cadmium (Ni-Cd) batteries for auxiliary power generation because they have a higher energy content per pound and sortie RAM missions do not require the long life and multiple recharge capability available from Ni-Cd batteries. Also, Ni-Cd batteries cost three to four times more than Ag-Zn batteries. The Ag-Zn batteries are a Skylab CSM battery design rated at 15 kW-hr. Each battery can be recharged six times (50 to 70 percent depth of discharge). The majority of the payloads require electrical energy ranging from 2.25 to 25.3 kW-hr over the six-day operating duration, and the batteries will be sized for this total six-day energy requirement. Some payloads (e.g., Material Science) have energy requirements varying from 14 to 45 kW-hr per day. At this level of requirement, battery recharging is justified for weight savings. The power levels for these experiments can rise to 30 kW, and additional power conditioning and wiring are included in the auxiliary kits to meet this demand.

3.1.1.5 Habitability. Habitability functions provide for the following crew needs: personal equipment, general equipment, furnishings, hygiene and waste, emergency and survival equipment, and food management. Implementation of these requirements for the sortie RAM is presented in Figure 3-17, for two payload crewmen, showing that the orbiter provides all living provisions for the crew. For this reason, only those habitability provisions necessary for performing experiment operations are located in the sortie RAM. These include mobility and restraint devices; miscellaneous items such as cleaning equipment, data, and tools; and emergency equipment such as oxygen masks and IVA suits.

Major habitability parameters upon which the sortie RAM design is based are: free volume of 750 cubic feet/man, work station lighting of 30 to 50 foot-candles, acoustic noise level inside the sortie RAM, as defined in Figure 3-18, and surface temperature of less than 105°F. These requirements were established to provide a pleasant and effective working environment for crewmen.

3.1.1.6 Communications. The orbiter provides all communication support for sortie RAM by sharing its VHF/TDRS links (voice, low-rate telemetry and command) and S-band links to the ground network (1 Mbps digital data transmission), as illustrated in Figure 3-19.

3.1.1.7 Data Management and Onboard Checkout Subsystems. The basic data-handling approach uses permanent digital tape and onboard data storage. Data is recorded with volumes ranging from 2×10^7 to 1.3×10^{12} bits per mission and at rates as high as 50 Mbps. The number of reels of tape carried for payloads range from 2 to 21. One 14-inch reel of 1-inch tape can store 62 Gb of data and accommodate nearly 72 percent

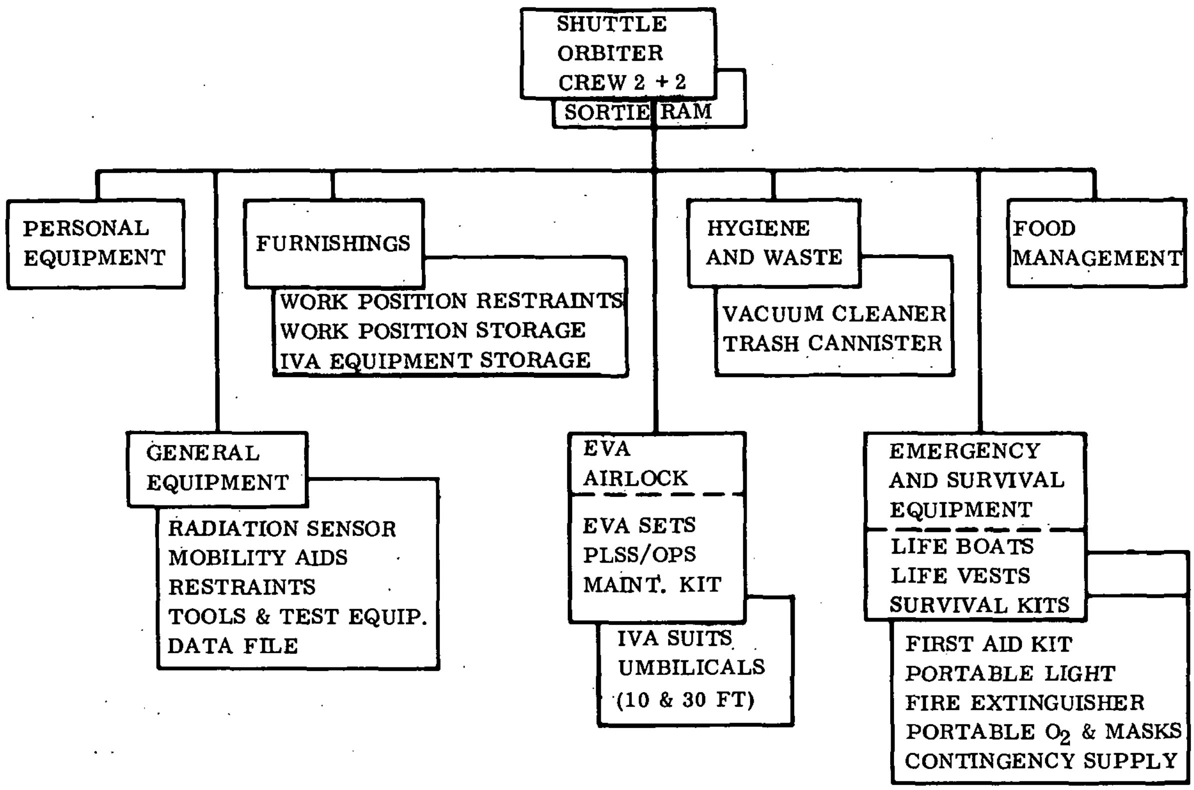


Figure 3-17. Habitability Provisions for Sortie RAM (Early Capability)

of the payloads. A limited number of payloads require near-real-time transmission of information with rates up to 1 Mbps.

Data management subsystem (DMS) major components are located in the sortie RAM (Figure 3-19). An upgraded version of the Skylab tape recorder (67 Mbps, 28 tracks, 20 kb/inch/track) is provided for digital recording. A high-rate switching and multiplex unit is hardwired to wideband experiment digital and the orbiter S-band system.

A full multiplex data acquisition and command distribution system is used to transfer signals between subsystems, experiments, the orbiter, and ground prelaunch equipment. Computer control of the multiplex system is via computer interface units. Digital interface units (DIUs) receive and transmit low-rate information over the full multiplex wire, decode instructions into functional commands, and provide a buffer for data generated by and sent to experiment sensors. Interface terminals, a low-rate formatter, and command decoders tie in to the orbiter communication link for telemetry and command and the orbiter guidance, navigation, and control inertial measuring unit to obtain information for astronomy experiment attitude control. Typically, as many as 1000 signals are associated with the subsystems and experiments. Seven DIUs are used to provide redundancy. The full multiplex wire also interfaces with the RAM pallet.

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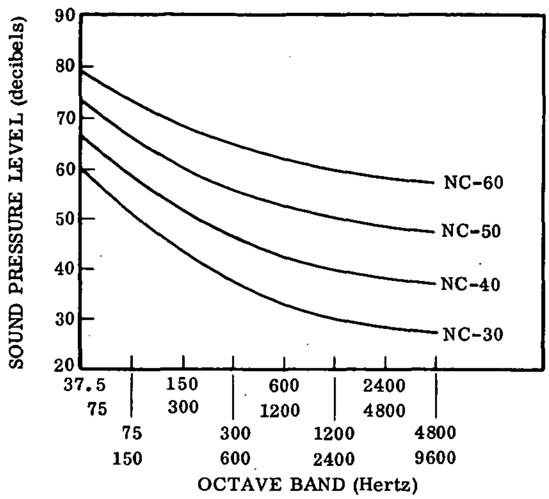


TAKEN FROM NASA REPORT MSC-03909, HABITABILITY DATA HANDBOOK, VOL. 2, ARCHITECTURE AND ENVIRONMENT, 31 JULY 1971.

NC CURVE	APPLICATION
NC-30	SLEEP/REST AREAS
NC-48	CONTROL AREAS WHERE COMMUNICATIONS ARE CRITICAL: AREAS WHERE SOME CONCENTRATION AND RELAXED COMMUNICATION MAY BE DESIRABLE (RADIO AND TELEVISION LISTENING)
NC-50	AREAS WHERE GOOD COMMUNICATION CONDITIONS ARE NOT ESSENTIAL (SOME DISTRACTION TO EXTERNAL NOISE CAN BE PERMITTED): INTERNAL NOISE GENERATION DUE TO OTHER ACTIVITIES MAY BE PRESENT: GENERAL WORK/LIVING AREAS
NC-60	MAINTENANCE AREAS (SHORT STAY TIME)

Figure 3-18. Noise Criteria Curves

Control, monitor, and automatic checkout of all subsystems and experiments is by a centralized computer configuration. Floating-point hardware is used and three computers provide redundancy. Software implementation features a modular structure under control of a hybrid executive. A separate software package is used for experiments and generalized for all subsystems. A higher-order language selected from those currently under development is proposed to reduce coding effort and provide simpler debugging, easier verification, and better documentation.

The onboard checkout subsystem (OCS) for sortie RAM is presented in Figure 3-20. It is an autonomous, flexible, job-oriented system that performs highly organized, repetitive functions (such as status monitoring) automatically while permitting crew participation in those functions performed periodically or on an as-needed basis (such as fault isolation, redundancy switching, and checkout). This versatility in applying degrees of automation to suit functional need is further extended to include the differences between the sortie RAM subsystems (which are relatively stable and lend themselves to automation) and the payload experimental equipment (which is continually varied and does not).

The onboard checkout system uses the communication and data management subsystem (CDMS) data processor, data distribution system and interfacing units. It supplies a stimuli generator to activate subsystems for checkout and fault isolation. It also provides a caution and warning (C&W) logic module, which monitors caution and warning conditions aboard sortie RAM. This function is performed concurrent with, but independent of, other checkout functions by the OCS. C&W signals are generated by the logic module and distributed by hardwire to the visual display and aural alarms

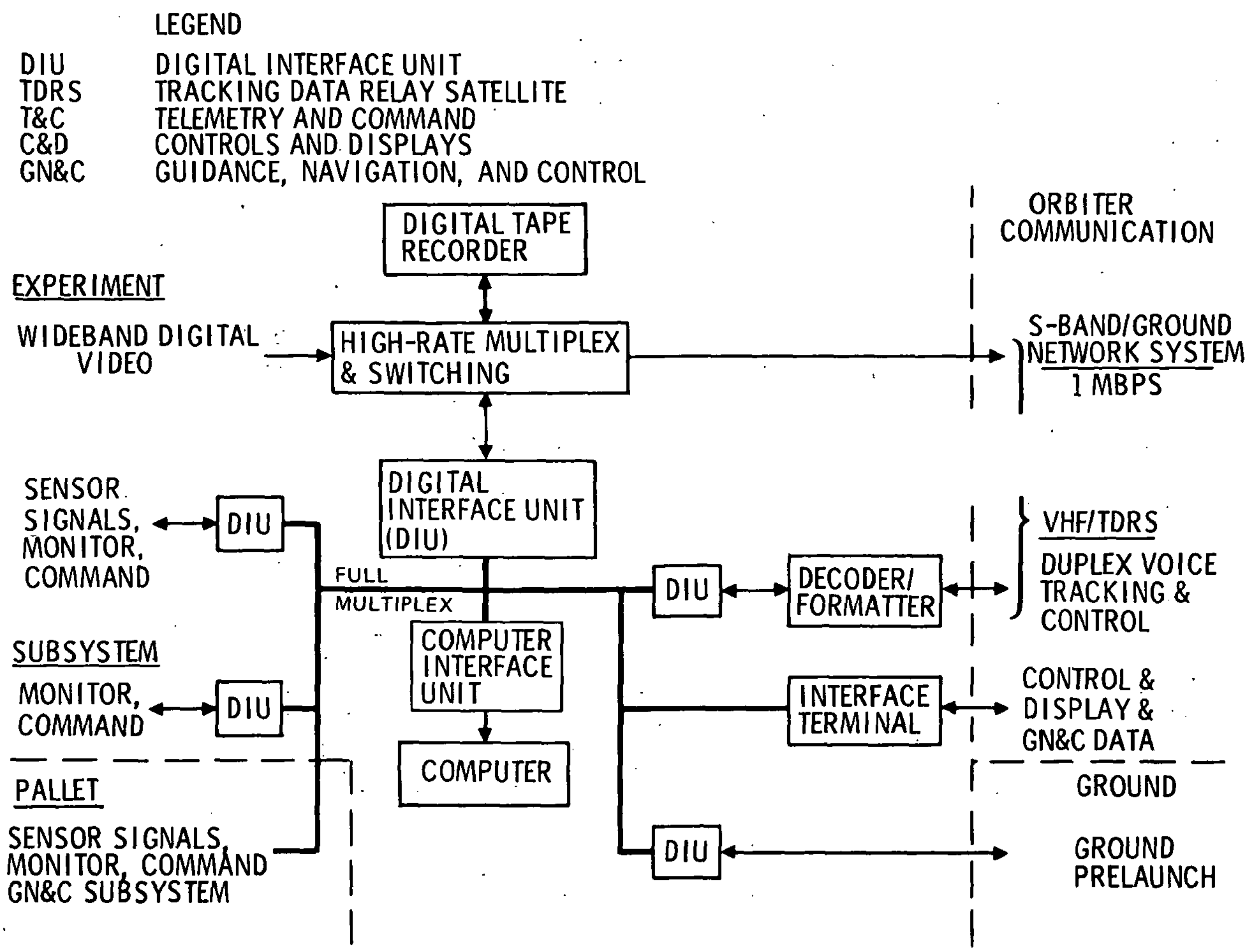


Figure 3-19. Sortie RAM CDMS

located in all habitable locations aboard the sortie RAM and to the orbiter. Signals are also generated and transmitted by hardwire to the computer for automatic response to the detected condition.

The C&W advises the crew members that there has been a malfunction that may be hazardous to the crew, the classification of the hazard (emergency, caution, or warning), and the identity of the specific hazard (e.g., temperature high, temperature low, etc.). The major criteria on which the system concept was developed are the need for a uniform man/machine interface and the need for an onboard autonomous system to provide absolute monitoring of physical life-critical parameters. Any out-of-tolerance conditions of these parameters would cause a potential crew hazard situation, and indication of these hazards must be immediately transmitted to the crew. There are two emergency conditions: fire and rapid pressure loss. When either of these conditions occurs, the C&W system will indicate the nature of the emergency audibly and visually. The emergency, warning, and caution audible indications are distinctly different, whereas the emergency and warning visual indications are identical.

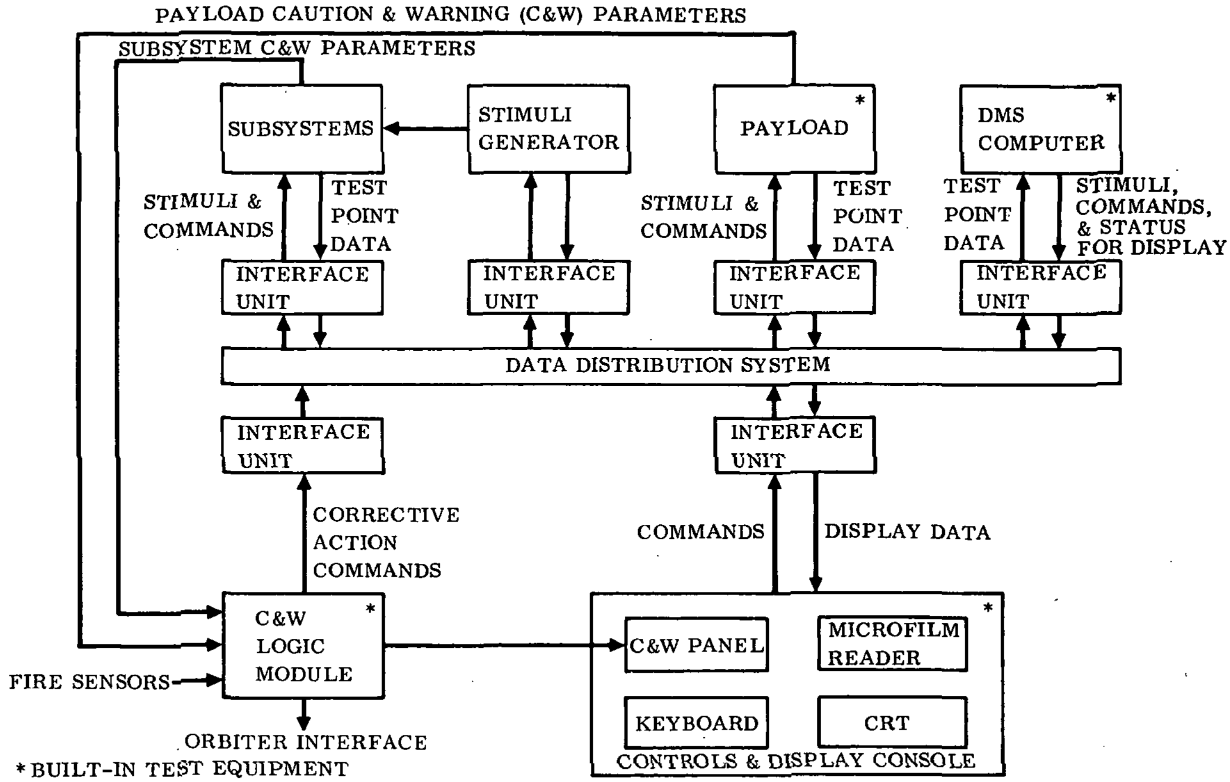


Figure 3-20. Sortie RAM OCS Configuration

The sortie RAM/orbiter interface allows C&W display and alarms from the sortie RAM to be seen in the orbiter and control responses from the orbiter (both cockpit and aft station) to direct subsystems in the sortie RAM. Such capability ensures crew cognizance of all C&W situations and response capability during all mission phases, whether the sortie RAM is manned or unmanned (such as during ascent and entry). From the orbiter commander's panel the only control available is to initiate response to a fire in the sortie RAM. All categories of C&W situation information are displayed and controls may be initiated at the orbiter aft station (third station). Typically, this station will be used to verify that sortie RAM is safe to enter (all subsystems functioning normally, atmosphere proper, etc.) prior to initiation of on-orbit operations. Figure 3-21 is a simplified diagram illustrating the sortie RAM/orbiter interface and operational details of the overall C&W function.

The OCS is also used during prelaunch checkout. It controls and monitors the activated sortie RAM subsystems during the launch readiness phase and during the boost and ascent phase from the control and display (C&D) located in the orbiter until on-orbit transfer of control to the sortie RAM is attained. At that point, OCS is autonomous with sortie RAM for on-orbit and experiment operations. For reentry and landing, control is reverted to the C&D console in the orbiter. Autonomous operations are again established in the sortie RAM while on the ground for postflight checkout and refurbishment.

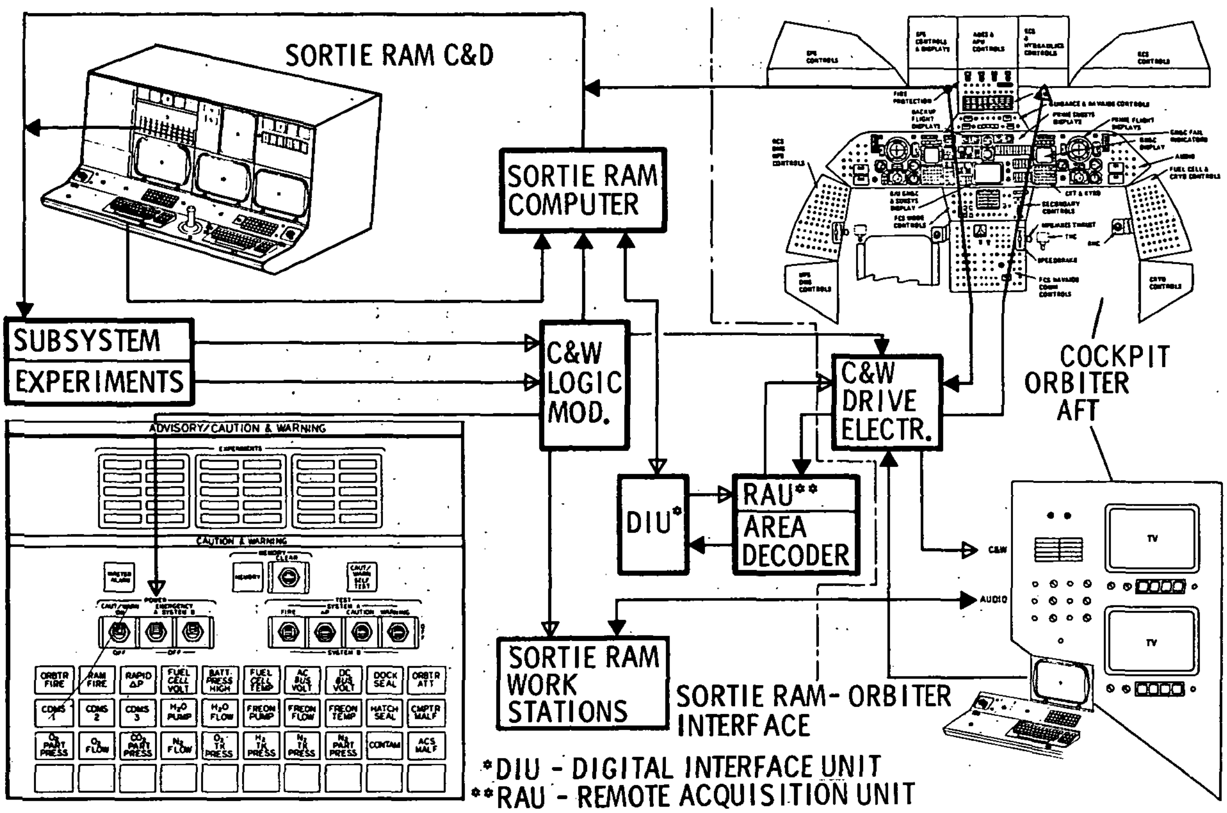


Figure 3-21. Sortie RAM/Shuttle C&W Interface

3.1.1.8 Control and Display (C&D) Subsystem. The C&D subsystem provides the major man/machine interface to effectively control and manage payload experiments and sortie RAM subsystems. The crew requires access to information in a form that facilitates their decision processes. This access must be capable of being used for several functions at the same time or at different phases of the mission.

The major functions provided by the C&D subsystem are to:

a. Provide a two-man C&D console for centralized management of subsystems and selected experiments, as desired.

b. Provide capability for experiment-dedicated unique C&D.

c. Provide caution and warning terminals indicating C&W situations.

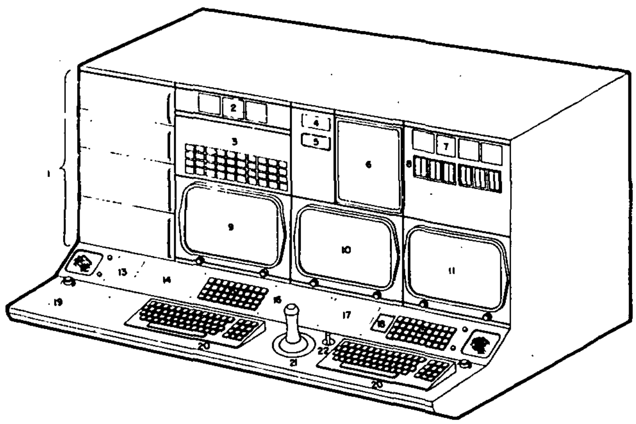
d. Provide audio communications.

e. Provide for closed-circuit television.

Control and Display Console

The centralized management of selected experiment and subsystem functions is provided by the data and subsystem console located in the sortie RAM. The console provides an optimum mix of conventional dedicated C&D and integrated, software-

oriented, multipurpose C&D. The console is a two-crewman C&D station, weighs 573 pounds, has a volume of 29 cubic feet, and consumes 540 Watts of power. Provisions are included to accept standard-panel-size, dedicated-experiment C&D, as shown in Figure 3-22.



1. DEDICATED EXPERIMENT CHASSIS
2. ADVISORY EXPERIMENT
3. CAUTION & WARNING
4. MISSION TIME
5. EVENT TIME
6. MICROFILM VIEWER
7. ADVISORY SUBSYSTEMS
8. DEDICATED SUBSYSTEMS C&D
9. CRT EXPERIMENT PRIMARY
10. CRT EXPERIMENT PRIMARY
11. CRT SUBSYSTEM & CLOSED CIRCUIT TV PRIMARY
12. INTERCOM SPEAKER
13. INTERCOM CONTROLS
14. LIGHTING
15. FUNCTION KEYBOARD
16. MONITOR SELECTION CONTROLS
17. CLOSED CIRCUIT TV COMMAND CONTROLS
18. CONSOLE EMERGENCY PWR
19. CONSOLE CIRCUIT BREAKERS & PWR DIST.
20. ALPHANUMERIC KEYBOARD
21. 3-AXIS CONTROLLER
22. 2-AXIS CONTROLLER

Figure 3-22. C&D Console

The data management computer provides the console with information through its interface with the subsystems and experiment payload. Digital interface units provide the interface to the data management computer via a multiplex bus allowing payload and subsystem C&D to be handled by software.

Audio Distribution

The audio distribution terminals use headsets and fixed speakers or microphones. Headset voice functions include duplex voice communications between payload crew and orbiter crew members as well as between payload crew themselves. Duplex voice communication with the ground is routed to the orbiter for transmission. The fixed speaker/microphone functions include simplex (talk or listen) voice communication between payload crew and orbiter crew members as well as between payload crew members themselves. The emergency audio station consists of a speaker/microphone that provides simplex voice communication between the sortie RAM and the orbiter via the emergency intercom bus. The interface with the caution and warning logic module for aural alarms is as shown in Figure 3-23.

Caution and Warning (C&W) Panels

C&W panels located on the data and subsystem console provide for display of C&W situation information. The master alarm and C&W indicators are activated when any emergency, caution, or warning situation is detected. Manual intervention is necessary to reset C&W indicators following corrective action.

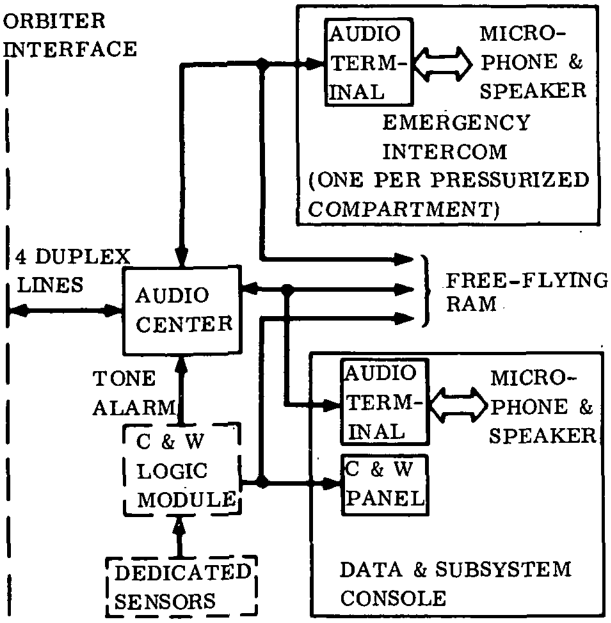


Figure 3-23. Sortie RAM Audio and C&W Distribution

Closed Circuit Television (CCTV)

Control and display is provided by the sortie RAM for CCTV cameras located to view equipment operation on the RAM pallet. The CCTV cameras and associated floodlights are located on the orbiter manipulator arms. An interface between the orbiter and sortie RAM will allow TV video to be displayed on the C&D console. The same interface will allow pan, tilt, and zoom of the CCTV cameras.

3.1.1.9 Guidance, Navigation and Control (GN&C) Subsystem. There are no GN&C provisions within the sortie RAM digital processor. For these payloads requiring stabilization and attitude control, the basic capabilities of the shuttle are used where they satisfy the payload stabilization and control requirements. For some payloads (Astronomy discipline), however, the driving performance requirement is all-attitude pointing to 0.5 arc-sec, which is well beyond the capability of the shuttle orbiter. This capability (Figure 3-24) is provided by experiment integration equipment mounted on the RAM pallet and consisting of a payload gimbaling assembly, fixed-head star trackers, a rate gyro package, and CMGs.

3.1.1.10 Thermal Control Subsystem (TCS). The basic heat transport system for the sortie RAM is shown in Figure 3-25. Water is used as the heat transfer fluid within habitable compartments to meet the requirements of nontoxicity and nonflammability. The water loop interfaces with the freon 21 heat transport fluid through the interloop heat exchanger. The freon loop is located outside the habitable compartments and transfers heat to the space radiator for rejection to space. Freon is used since the radiator temperature can be well below the freezing point for water in some cases. A bypass valve around the radiator regulates the freon temperature to 35°F and provides control for variations in internal and external loads. For closed-shuttle-door operation and transient peak heating periods, a water sublimator and thermal storage element (TSE) are provided. An interface heat exchanger (GSE Hx) receiving coolant from ground support equipment is used during prelaunch and postlanding operations. The TCS interfaces with the EC/LS subsystem at the air-to-liquid heat exchangers. Cabin sensible and latent loads are absorbed at this point by the TCS. Freon is also used to warm the cabin oxygen supply.

There are two completely independent systems, with each system capable of carrying the entire cooling load and thereby providing redundancy in case of component failure. Each fluid loop in the primary system has one active and one standby pump. The

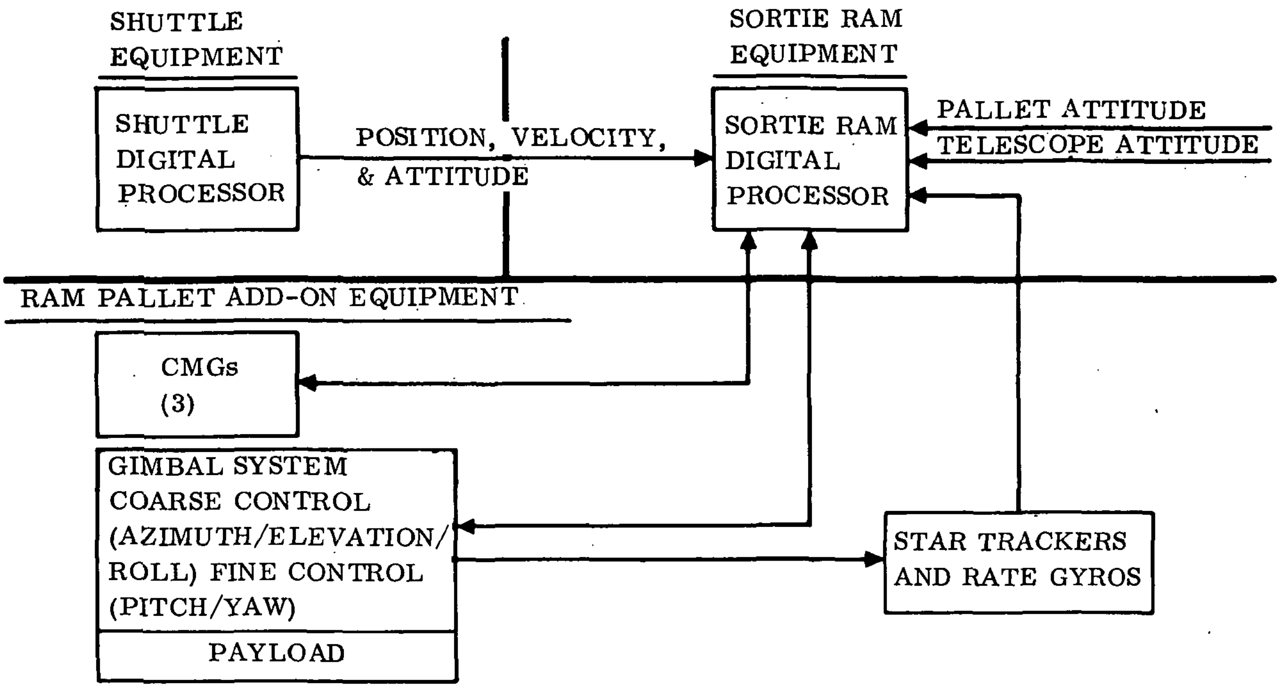


Figure 3-24. Sortie RAM GN&C Representation

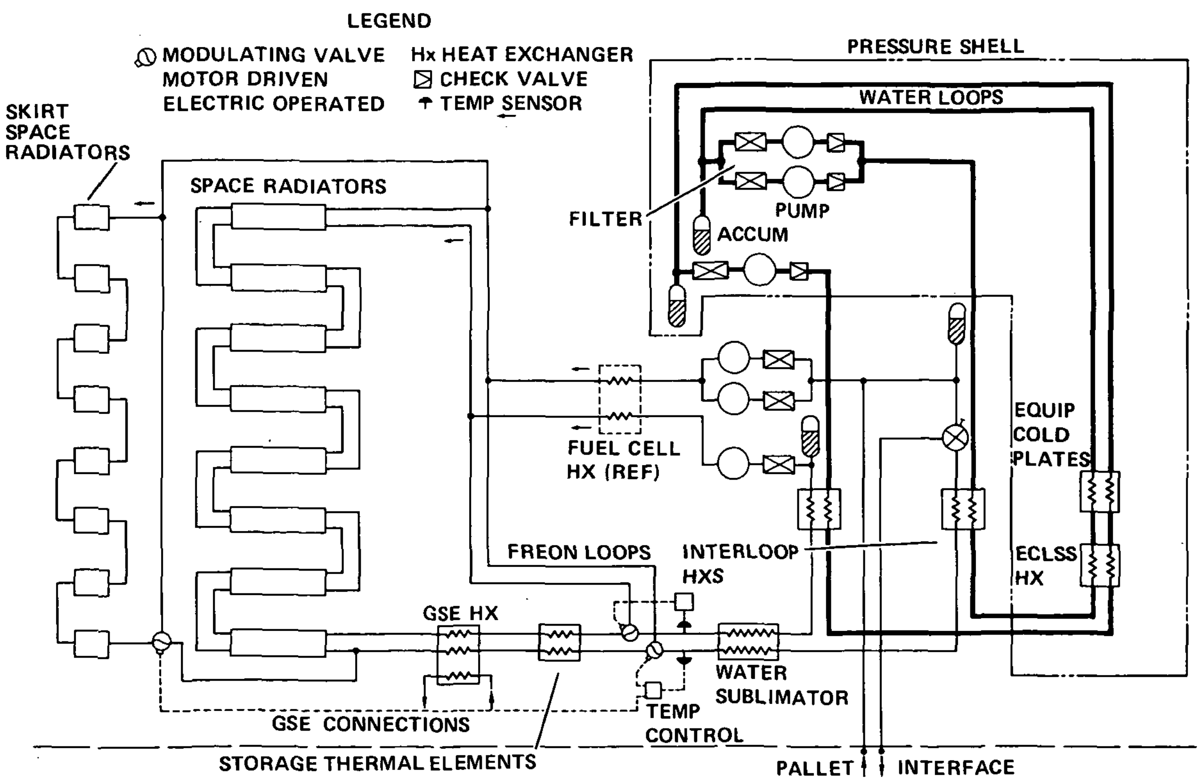


Figure 3-25. Sortie RAM Thermal Control Subsystem Schematic

system satisfies the failure modes and effects analysis criteria. Radiators on the skirt do not contain redundant coolant loops, since the experiments can be powered-down in the event of failures to reduce cooling requirements to within the capability of basic sortie RAM radiators. The basic components should be available or under development from shuttle or other space programs.

The selected radiator configuration has 3/16-inch inner diameter longitudinal tubes spaced eight inches apart and attached to the 0.016-inch-thick outer meteoroid shield. There are eight redundant tubes on each panel interspaced between the active tubes. A RAM element radiator consists of eight series panels around the circumference of the vehicle, and each panel consists of eight parallel tubes. A 5-mil Teflon-silver coating was selected for the radiators. For sortie missions, Teflon-silver is about 10 percent better than the usual space white paint, Z-93, and does not require radiator panel bypass valves. The degraded coating characteristics for Teflon-silver used in the sortie RAM performance analysis are 0.09 for absorptance and 0.80 for emissivity. Radiator performance depends on the surface and vehicle orientation.

The TCS was analyzed for the 3-sigma conditions, i.e., a combination of the most severe space heating environment together with the most severe orbit that imposes the highest heating load on the TCS radiators. In addition, the major TCS components were selected to coincide with those proposed for the shuttle orbiter to maximize commonality and to minimize development costs wherever it appeared practical. Thus, no optimization of those components was undertaken to improve TCS performance. Effects of the radiator shadowing were also taken into account.

One measure of the degree of conservatism inherent in the analysis is shown in Figure 3-26, which depicts the sortie RAM radiator heat-rejection capability versus cabin air temperature for the most severe orbit with +3 sigma and the nominal heating conditions. For a selected cabin air temperature, the net heat rejection by the TCS is increased by more than 2500 Btu per hour when operating in a nominal instead of a +3 sigma space heating environment. The heat-rejection capability of the sortie RAM for various orientations while maintaining a cabin temperature of 65°F is given in Table 3-3.

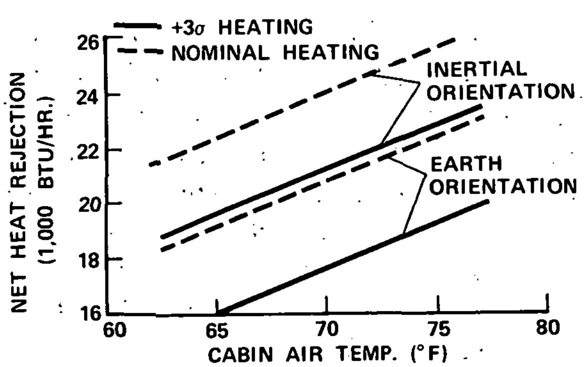


Figure 3-26. Sortie RAM Radiator Performance for Worst Orbit

There are 6 payloads (out of 21) that require cabin air temperature above the 65°F design range (approximately 72°F) for the +3 sigma worst-case orbits. However, for nominal heating conditions and/or proper scheduling of launches, no problems are expected in providing the range of cabin temperature control.

Table 3-3. Sortie RAM Heat Rejection Capability

Orientation	Space Heating (Btu/hr)	
	+3 Sigma	Nominal
Earth	16,150	18,650
Inertial	19,600	22,000
Away From Earth	20,700	23,200

3.1.1.11 Mass Properties. The estimated mass properties (weight, center of gravity, moment of inertia, and product of inertia) of the basic sortie RAM and the sortie RAM for free-flying RAM servicing are presented in Table 3-4. These properties were estimated based on an analysis of the configuration design features and subsystem data described in this section for sortie RAM. Allowances for installation hardware and for details not defined in the preliminary design drawings were included in the estimates. The weight breakdown format in Table 3-4 complies with MIL-M-38310A requirements.

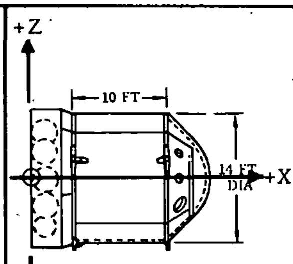
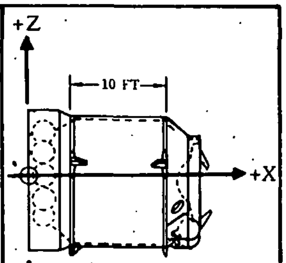
The weights shown in Table 3-4 are for factory-complete articles without items that must be added to the sortie RAM and servicer for specific missions: subsystem add-ons, experiments, crew equipment, residuals, reserves, and expendables. Payload details and weights are presented in Section 6. By Level I RAM project guidelines, the dry weight for the sortie RAM is limited to 20,000 pounds.

3.1.1.12 User Provisions. Table 3-5 describes the provisions and capabilities in the sortie RAM for the performance and support of experiments. The net capability for experiments is derived by subtracting resource and subsystem requirements from the total sortie RAM capability.

The sortie RAM is restricted to a crew of two with a maximum net of 21.5 hours per day for experimentation. About 4.4 kW or more of the original 7-kW fuel cell power is available for experimental equipment. Included in this amount is a maximum of 1.5 kW of regulated dc voltage and 1.25 kva of regulated ac voltage. In addition, 40 kW-hr of peak power is available from batteries that can be recharged from fuel cells. The selected tape recorder has a maximum input rate of 67 Mbps and a storage capacity of 6.2×10^{10} bits per reel. Provision is available on the sortie RAM for storage of up to 21 reels of magnetic tape. Control and display is by a central console that includes provisions for payload-dedicated C&D in standard panel sizes. All communication capability as well as guidance, navigation, and control is provided by the shuttle.

The air temperature of the thermal control system for experimental equipment varies from about 80°F at zero Btu/hr heat rejection to about 100°F at 3100 Btu/hr heat rejection. The total available heat rejection for all systems is 20,700 Btu/hr when the sortie RAM is pointed away from the earth; heat rejection is slightly lower when the

Table 3-4. Basic* Sortie RAM Element Mass Properties

Subsystems (MIL-M-38310A)	 Sortie RAM	 Free Flyer Servicer
Structure	3717	3717
Induced Environmental Protection	1531	1531
Docking	238	476
Prime Power Source	1046	1046
Electrical Conversion and Distribution	314	314
On-Board Checkout	18	18
Data Management	320	290
Displays and Controls	663	663
Electrical Wiring	423	423
Atmospheric Control	562	866
Thermal Control	898	898
Life Support	166	166
Interiors	320	320
Basic Weight (lb)	10216	10728
Center of Gravity Location (inches from datum on sketch)		
X	85	91
Y	-5.1	-4.7
Z	+5.3	+3.3
Mass Moment of Inertia About CG (slug-ft^2)		
I_{XX}	10440	10840
I_{YY}	12680	14550
I_{ZZ}	13160	14820
Product of Inertia About CG (slug-ft^2)		
I_{XY}	241	304
I_{YZ}	72	61
I_{XZ}	-987	-1480

*Factory complete condition. Excludes subsystem add-ons, experiments, crew and crew equipment, reserves, residuals, and in-flight losses.

Table 3-5. Sortie RAM Support Capabilities

Parameter	Total Capability	Net Capability for Experiments	Remarks
1. Volume (ft^3)	1950	750	
2. Crew size/manhours per day	2/24	2/21.5	Habitability provided by shuttle.
3. Electrical Power			
Total, unregulated (±15%)	7.0 kW, 1034 kW-hr	≥4.4, 600 kW-hr	
28 vdc ±5%/115 vac, 400 Hz		1.5 kW/1.25 kva	
4. Data Acquisition			
Max data rate	67 Mbps	67 Mbps	
Storage (b/reel/No. of reels)	$6.2 \times 10^{10}/21$	$6.2 \times 10^{10}/21$	
5. Control and Display	Includes subsystem dedicated C&D	Payload dedicated C&D console Mission event timers Caution and warning Intercom	
6. Communications Transmission capacity	Ground Network 1 Mbps peak 11% coverage	Ground Network 1 Mbps peak 11% coverage	Shuttle provided
7. Guidance, Navigation, & Control			
Pointing Acc. (deg)/stab. (deg/sec)	±0.5/±0.03	±0.5/±0.03	Shuttle provided
Position (n. mi.)/velocity (fps)	±1.0/±10	±1.0/±10	
8. Thermal Control			
Air temp/heat rejection	20,700 Btu/hr	80 to 100° F/0 to 3100 Btu/hr	Total heat rejection rate is for RAM pointed away from earth.
Cold plate temp/heat rejection		85 to 95° F/0 to 3100 Btu/hr	
9. Viewports	Three 12-inch-diameter viewports located at aft 45-degree conical section provide hemispherical coverage.	Three 12-inch-diameter viewports located at aft 45-degree conical section provide hemispherical coverage.	
10. Feedthroughs	Two 8-inch-diameter feedthrough ports located at aft 45-degree conical section.	Two 8-inch-diameter feedthrough ports located at aft 45-degree conical section.	

sortie RAM is pointed toward earth or for stellar orientation. The viewports and feed-throughs described in the table are provided by the RAM to enhance experiment operation capability.

Optional integration equipment to further enhance payload carrier capability is described in Section 6.4.

3.1.2 RAM SUPPORT MODULE (RSM)

3.1.2.1 Configuration. The RSM is the pressurized RAM element that supplies added payload crew capability to the experiment program. It is always used with a RAM payload module and is characterized by the added habitability provisions for the additional payload/mission specialists not carried in the orbiter.

The RSM is a direct evolution from the sortie RAM, and conversion from one to the other is comparatively simple. Much of the sortie RAM design is based on the requirements established for the RSM. This is especially evident in the EC/LS subsystem and its ducting and the EPS and its wire-way routing. The floor was also based on RSM needs relative to bunk and couch locations and a rapid egress path.

The RSM is used in one configuration only, exclusive of changes for crew size. Major features of the RSM are:

a. Overall length is 18 feet; nominal diameter across the main hull is 14 feet.

b. The baseline crew capability is 2+2+4; i.e., two orbiter crewmen and six payload crewmen with two payload crewmen housed in orbiter and four in the RSM.

c. The interior arrangement consists of a control and display console and fixed habitability equipment, including four sleep compartments, for the maximum-size crew.

d. Interfaces with the orbiter and shuttle ground support facilities are at the forward end of RSM. The interface with orbiter permits crew movement between the RSM and the orbiter.

e. Interface with the RAM payload module is provided at the aft end of RSM. This permits crew movement between the RSM and the RAM payload module.

Table 3-6 lists the more pertinent characteristics of RSM. The inboard profile (left hand side) and a perspective of the RSM are presented in Figure 3-27.

External Arrangement

As in the sortie RAM, the RSM primary structure consists of a 160-inch-diameter waffle skin constant-section cylinder 120 inches long with an 8-inch-deep frame at each end. A 45-degree conic section is attached at each end of the cylinder and truncated by

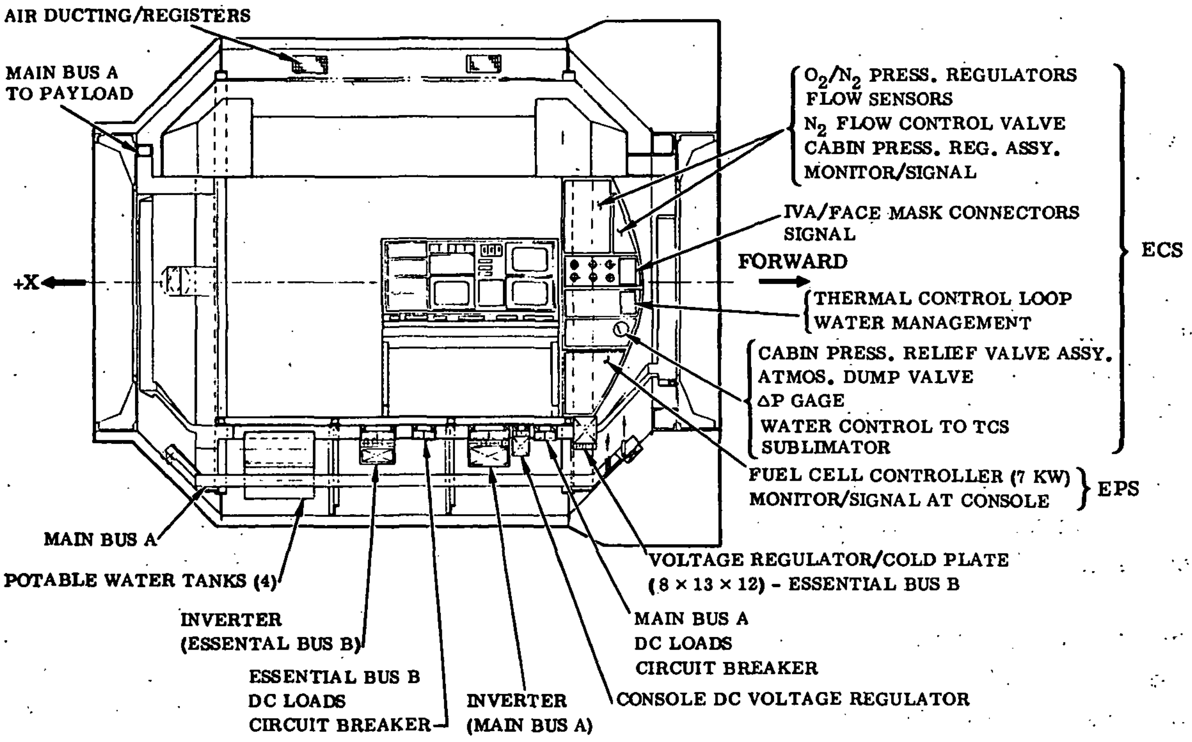
Table 3-6. RSM Characteristics

Parameter	Basic Configuration
Overall Length	225.0 in. (18.75 ft)
Constant Section Side Wall Length	120.0 in. (10.0 ft)
Internal Diameter, Pressure Shell	160.0 in. (13.33 ft)
External Diameter, Radiator/Meteoroid Bumper	168.0 in. (14.0 ft)
Maximum Diameter (Fwd Radiator)	180.0 in. (15.0 ft)
Internal Volume	1950 ft^3
Floor Arrangement	Longitudinal
Support Fittings Orbiter Attach (Quantity)	3
Hatches	1 at 60.0 in. dia.
Viewports	3 at 12.0 in. dia aft cone 1 at 6.0 in. dia., hatch
Crew Complement (orbit crew + payload crew located in orbiter + payload crew located in RSM)	2+2+2 Baseline 2+2+4 Provisions for
Mission Duration	7 Days Nominal
Electrical Power System	
Power Source	1-7 kW Cont Duty Fuel Cell
LO_2 Tanks, 33.0 O.D.	2-Shared with L.S.
LH_2 Tanks, 33.0 O.D.	3
Distribution Voltage	28 vdc
Maximum Energy Capacity	1034 kW-hr
Power Peaking Batteries (Add-on)	500 AH Ag-Zn
EC/LS (Independent System)	
Atmosphere Pressure	14.7 psia; pp O_2=3.1 psia
pp CO_2	5 mm Hg
Atmosphere Temperature	Selectable 65° to 85°F
Waste Water Tanks, 3100 $in.^3$	1
H_2O By-Product Storage Tanks, 3100 $in.^3$	7
N_2 Tanks 25.3 O.D; 3100 psia	2 on -X Cone
CO_2 Removal	LiOH
TCS (Two Loop, Radiator Bypass System)	
External Loop	Freon 21
Internal Loop	H_2O
Equipment Cooling	Cold Plate and Air
Radiator Area	531 ft^2
Ascent/Descent Cooling & Transient Peaks	Sublimator & Therm. Stor.
Cooling Capacity, Radiator	16,100 Btu/hr minimum
Prelaunch & Post Landing	GSE
Communications	Shuttle Provided Hardline to Orbiter VHF/TDRS Voice Low Rate Data & CMD S-band -1 Mbps data
Data Management System	
Data Handling	Tape Recording 50 Mbps 50 Mbps $- 2.3 \times 10^{12}$ Bits/ Mission
Processing	Central Computer
Acquisition & Command Distribution	Full Multiplex
Checkout, Fault Isolation	Integrated Into DMS
Controls and Displays Console	2-Man Integrated Console
Habitability	
IVA Suits, Umbilicals	0 Suits, 4 Umbilicals
IVA Stations	1
Bunks	2 (2+2+2 crew) Baseline 4 (2+2+4 crew) Provisions for
Launch/Re-entry Couches	2 (2+2+2 crew) Baseline 4 (2+2+4 crew) Provisions for
Weight, Dry (Without Payload and Expendables)	10,887

a 102-inch-diamter bolting flange normal to cylinder centerline. The forward conical section is mated to an interface adapter assembly that physically interfaces with the orbiter. This adapter assembly is basically a space station docking assembly without the docking frame, attenuator/actuators, hydraulic/ air power systems, and associated controls. The conical section at the aft end has a similar interface adapter assembly mated to the forward conical section. This adapter assembly interfaces with the RAM payload module.

The equipment bay is wrapped around the forward conical section (Figure 3-27). This space is enclosed by a peripheral 3-foot-long radiator extending aft from the orbiter interface plane, six access panels at the interface plane, and six access panels bridging the space between the radiator panels on the equipment bay and the cylindrical section. Due to the selection of storage tanks from space shuttle Phase B studies for commonality, the diameter across the radiator panels is 15 feet, which is the maximum envelope allowed. Located within the equipment bay, are two cryogenic-oxygen tanks, three cryogenic-hydrogen tanks, two nitrogen gas tanks, one fuel cell, fuel cell ancillary equipment, thermal control essential components, and a ground disconnect panel for those ground services required up until T-5 seconds before liftoff.

The forward conical transition section is pierced by four feedthroughs for fuel cell cabling and all forward external control and monitor circuits, water plumbing, gaseous oxygen and nitrogen, and the cabin atmosphere relief and vent valve.



ELEVATION VIEW — LEFT HAND SIDE

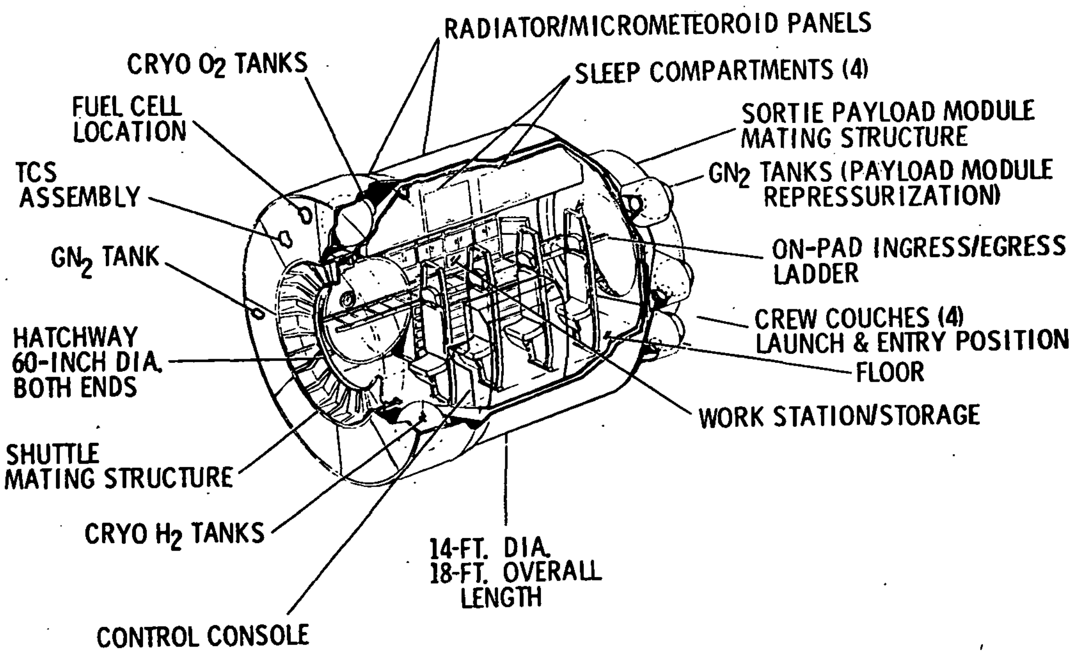


Figure 3-27. RAM Support Module

External to the constant-diameter section of the pressure hull and the aft conical section is protective insulation and an integrated radiator/meteoroid bumper. The radiator/meteoroid bumper consists of eight similar panels covering the entire periphery.

Panels at each end of the constant-diameter section permit access to a structural mounting ring at the juncture of the constant-diameter section with the conical sections. The structural mounting rings (Figure 3-28) are extensions of the end frame. These rings (one forward and one aft) are the primary mounting points for subsystem tanks and components. The forward ring is the primary structural base for three orbiter attachment fittings. By removing the access panels, two hoist fittings on the top side may be bolted onto the ring and two fittings on the lower side of the ring may be added for ground support and air shipment.

The aft ring is the primary structural base for two hoist fittings topside, and two GSE drag load fittings on the lower side. It is also used for mounting certain equipment apparatus. The hoist and ground/shipping fittings are not flight hardware.

The aft conical section is penetrated in seven places, as shown in Figure 3-29. Three 12-inch-diameter clear viewports are located 120 degrees apart. Two subsystem feedthroughs are located on the Y axes and each provides electrical power and lines for control and data circuits. These two feedthroughs supply the experiment equipment located in the RAM payload module. Two feedthroughs are provided at 30 degrees up

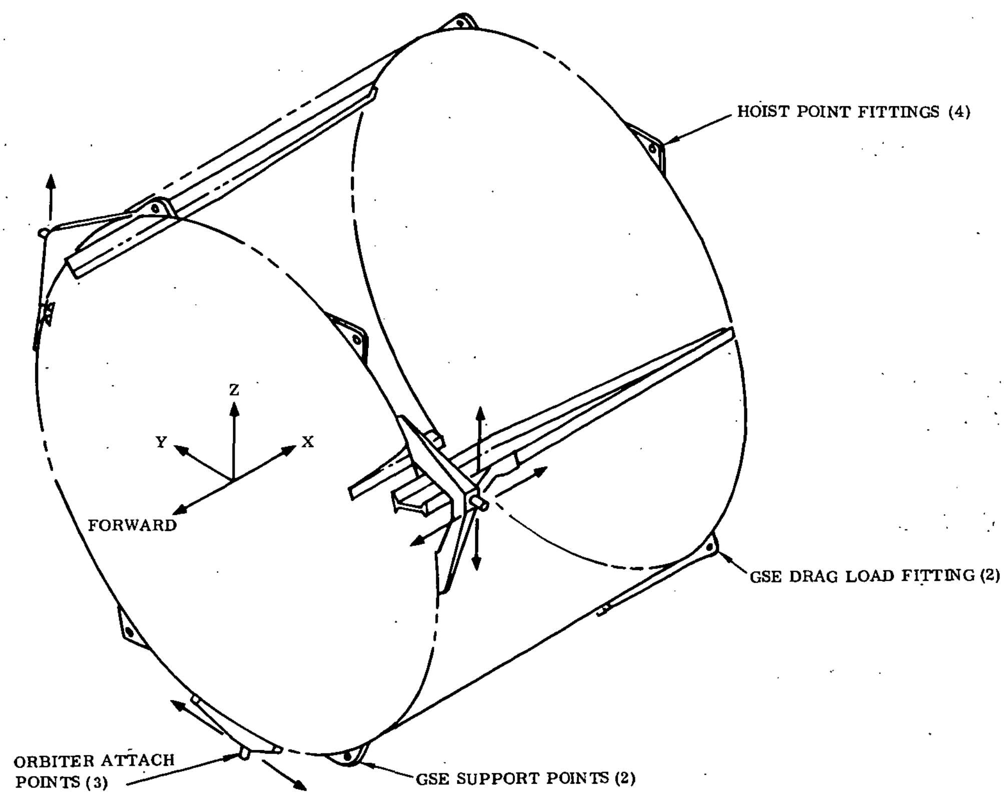


Figure 3-28. RSM External Structural Attachments

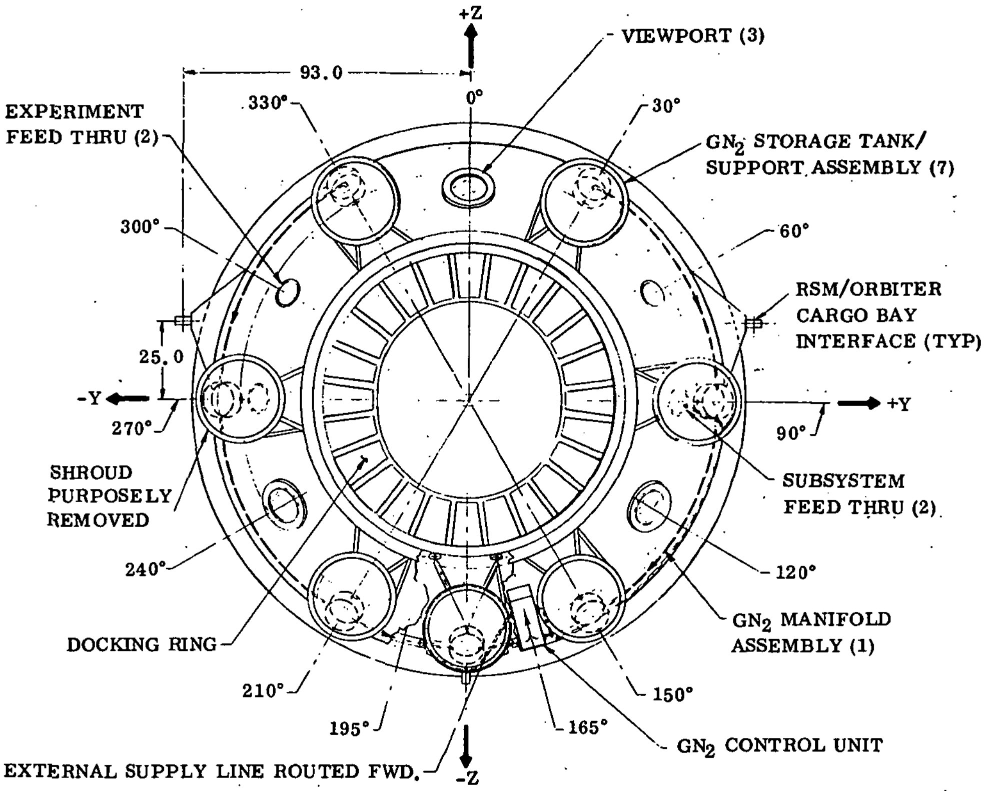


Figure 3-29. RSM Aft Conical Section

from the Y-Y horizontal plane on each side of the module for experimenter use for obtaining data to support their experiment.

Internal Arrangement

The internal architectural features of the RSM are styled by the horizontal floor arrangement and sleeping quarters. Figure 3-30 shows plan views of the floor and sleep compartments.

Interior secondary structure includes four overhead sleeping compartments, storage volume, air ducting, and utility runs. A horizontal floor is located 82 inches below the sleep compartments (46 inches below Y-Y axis) and provides the platform for mounting interior subsystems, growth equipment, the controls and displays console, and work surfaces. The working envelope extends from 46 inches below the horizontal centerline to 36 inches above the horizontal centerline, providing a floor-to-ceiling height of 82 inches.

The volume above the ceiling (36 inches above centerline) is dedicated to sleeping compartments and storage. The volume 46 inches below the centerline is dedicated to the floor and subsystems (EPS, EC/LS, water management, etc.).

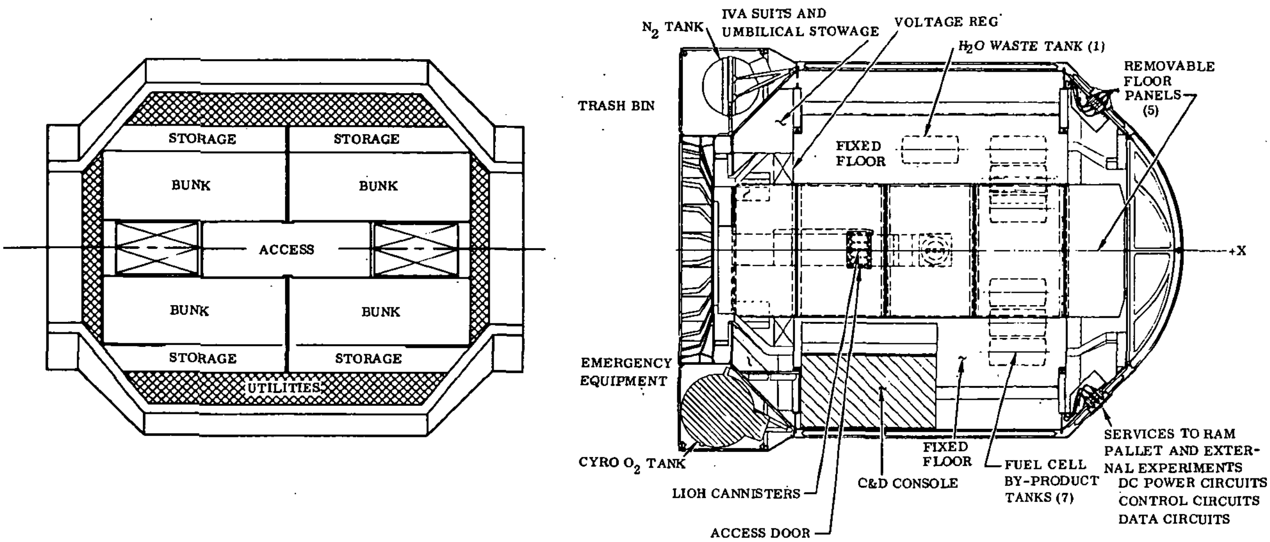


Figure 3-30. RSM Floor and Sleeping Compartment Arrangement, Plan Views

The RSM is designed to support a maximum of four crewmen during launch and landing and for sleeping and on-orbit operations. Couches are provided so that these crewmen can survive the launch and landing loads. These couches are easily installed and are removed and stowed for on-orbit operations. Access to the couches from the orbiter when on the pad is via a vertical ladder (X plane). The four couches are assembled one behind the other along the length of the module on the left-hand side of the ladder, which is approximately on the centerline axis.

The forward side-opening hatch opens over 90 degrees to the right side and is normally open except when the RSM is being deployed to an orbiter docking port using manipulators or under certain emergency conditions. The aft end has no hatch, since the RAM payload module is always connected and has a hatch in the forward end to provide isolation between the modules if desired.

The RSM contains an independent EC/LS subsystem identical to sortie RAM (Figure 3-8). The active components are located under the floor, with ducting routed forward then around the +Y side of the 102-inch-diameter cylindrical section using the 8-inch extension as a portion of the duct. This duct exits at the top, follows the 45-degree transition cone to the 160-inch-diameter section, goes aft along the +Z side of the hull constant section, down the aft 45-degree transition cone, around the 102-inch bolt ring, and exits on the right side of the interface adapter assembly. The central duct across the top (+Z) brings recycled air to the sleeping compartments. Each sleeping compartment

has an individual register located in the side of the duct so that each crewman can control the flow of air in his compartment. The lower portion of this duct, between the stowage volumes and above the crew access areas, is made from a perforated plate, allowing ample flow of air from the duct to the center aisleway and working volume below. The air is returned to the EC/LS conditioning unit via four open-floor areas at the intersection of the end conical sections and the removable and side floor panels.

The electrical power subsystem (EPS) provides two power sources, primary and essential:

a. The 7-kW fuel cell is the primary source, with power distributed by the main bus to support all subsystem and experiment loads.

b. If the primary system fails, the orbiter will provide power to operate the essential components of the EC/LS subsystem, lights, communication, and status display. This power is provided to the RSM through two separate cables that penetrate the RSM forward bulkhead and connect to wireways leading to Essential Bus A, under the floor on the left-hand side, and (separately) to Essential Bus B under the floor on the right-hand side. The essential buses are physically isolated to the maximum extent possible.

Other major components of the EPS are located under the floor, on and behind the secondary control panel, on the control console, and internally throughout the module as required. The power/signal distribution system comprises a series of wireways that conduct and protect the wiring to the point of use.

The RSM thermal control system is a dual-loop system using water as the heat transfer fluid within habitable compartments. The water loop interfaces with a freon heat-transfer fluid through an interloop heat exchanger. The freon loop is located outside the habitable compartment and transfers heat to the space radiators for rejection to space. A second freon loop is provided for redundancy. A water sublimator and thermal storage element are provided for closed shuttle cargo bay door operation and during operational periods when heating loads are above the capacity of the dual-loop system.

The water pump package and accumulators are mounted inside the forward conical transition section. Internal water coolant is plumbed to cold plates in the C&D console, to the communications/data enclosure above the console, to the EPS components under the floor, and into the utilities trough.

The major equipment item (exclusive of experiment payloads) is the control and display console located on the left-hand side at the extreme forward end of the constant section. Forward of this console in the 45-degree cone area is a control panel containing the IVA/face mask station, atmosphere regulation and control components, thermal regulation components, water mangement components, cabin relief and dump valving, and the fuel cell controller. Components of the communication and data system are located above

the console. Emergency equipment (such as first aid kit, portable lights, and fire extinguisher) are located on the left-hand side in the forward conical section just below the ECS control panel. Two trash collector bins are located under and attached to the forward removable floor panel. Housekeeping provisions (vacuum, cloths, bags, etc.) are stowed in a cabinet on the right-hand side in the conical section just below the TCS water pump package.

3.1.2.2 Structure. The RSM structure (Figure 3-31) consists of a 160-inch-diameter cylindrical section 120 inches long sandwiched between two 45-degree conical bulkheads. The forward end has a barrel section 102 inches in diameter and 8 inches long attached to the conical bulkhead and to the docking adapter. The aft end has a similar docking adapter without the special 8-inch-long by 102-inch-diameter adapter.

Mating Structure/Docking Adapter

The docking adapter carried throughout this study is the design developed for the modular space station and identified by the MDAC Drawing 1B80190. It is an integrally machined adapter section made from a 2219-T852 Al-alloy ring forging 102 inches in diameter and 15 inches long. It houses the androgynous docking system, if required, which used a square docking frame. The docking frame is manipulated with eight hydraulic/air attenuator actuators and has a latching system with provision for 12 active latches each side of the interface. It incorporates a 98-inch-diameter inflatable seal at the interface. It also has a nominally 60-inch-diameter hatch on the centerline. The docking adapter can be attached to the conical bulkhead at the 102-inch diameter using a bolt-ring flange and static seal.

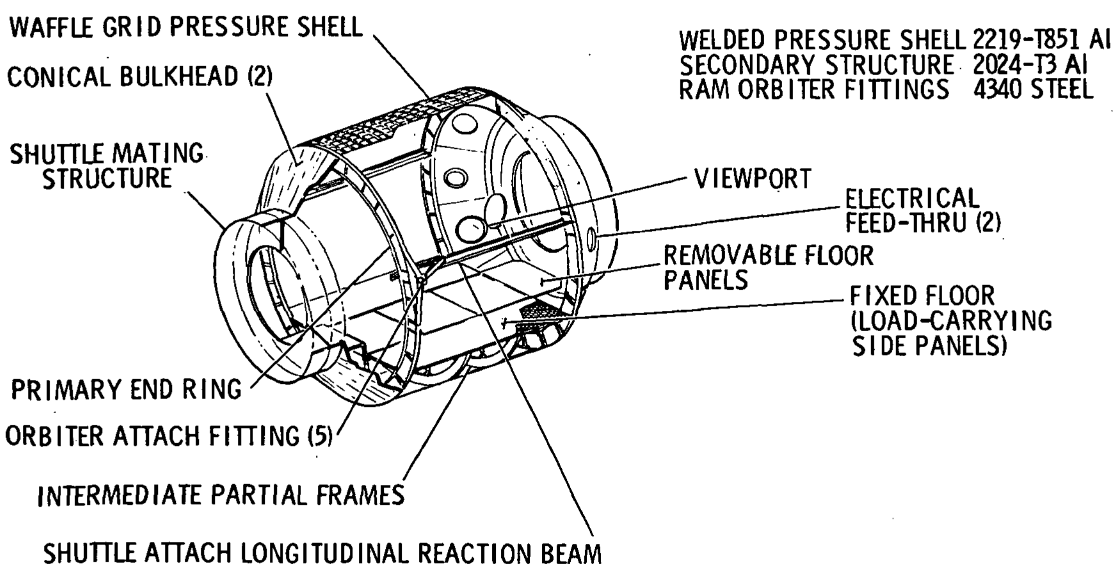


Figure 3-31. RSM Structural Arrangement

102.0-Inch-Diameter Adapter

This adapter is made from a one-piece roll-ring forging of 2219-T852 aluminum alloy as an integrally machined thick-wall cylinder with end bolt-circle flanges.

Cylindrical Sidewalls

The cylindrical section consists of three panels 120 inches long formed to the 160-inch-inside diameter. It has two primary end rings 8 inches deep and with I cross-sections. Two longitudinal I beams are welded into the cylindrical section at a location approximately 15 degrees above the horizontal centerline. The beam at the -Y, the left side looking forward, is 12 inches deep. The other beam is 3 inches deep.

The three segments of the cylinder span between the two beams and from these beams to the bottom centerline. The cylindrical panels are made with integrally machined waffle-grid stiffeners. The type of waffle selected is a 5-inch 20-degree square grid with the stiffeners on the outside of the module. The grid is 1 inch deep, the stiffeners are 0.050 inch thick, and the skin thickness is 0.070 inch. The cylindrical panels, the primary rings, and the horizontal beams are made from 2219 aluminum alloy.

Conical Bulkhead

The 45-degree conical bulkhead provides the transition between the 160-inch-diameter cylindrical sidewall and the docking adapter. The bulkheads are made from three segments welded together at a longitudinal seam, each segment consisting of a 0.055-inch skin with longitudinal and integrally machined blade stiffeners 1 inch high and 0.10 inch wide. Each segment also has an integrally machined frame for the windows.

The attachment to the cylinder is at a welded joint at the kick ring (primary end ring). The 102-inch-diameter interface is a bolt ring welded to the cone. These bulkheads are also made from 2219 aluminum alloy.

Secondary Structure

The secondary structure comprises the floors, the utility tunnels and ceiling components, and the external equipment support structure. The floors are horizontal (i.e., parallel to the X-Y axis) and are made from two fixed sections running along each wall with five removable 60-inch-wide panels through the center. The fixed sections are 3-inch-deep aluminum honeycomb, and the removable panels are 1-inch-deep aluminum honeycomb.

The 3-inch-deep side panels are 31 inches wide by 124 inches long, extending between the outer edge of the circumferential ring caps. The edges of the panels are finished by bonding 3-inch-deep channel and zee sections between the face sheets. The zee sections are toward the center and pressure wall (Y plane) and the channel sections are at the ends. The zee at the outer edge is supported by a drag angle secured to the pressure wall and to the circumferential rings on each end.

Support along the inboard edge of the panels consists of four vertical tubular struts extending to the circumferential rings and two intermediate partial frames. The partial frames are J-sections attached to the pressure wall and run circumferentially under the floor between the floor intersections with the pressure shell.

Spanning the 60 inches between the side floor panels are four intercostals equally spaced (40 inches on center) between the centers of the circumferential frames. The intercostals are hat sections, the flanges of which are secured to the protruding leg of the side panels.

The center section panels are of aluminum honeycomb sandwich construction. The edges are closed out by either a 1-inch-deep channel or a zee section. Zee sections are along the forward and aft edges (the legs securing to the intercostals), and the channel sections are adjacent to the side panels. These panels are removable and are supported by the intercostals only. The aft panel attaches along its forward edge to the aft intercostal and is clipped at two places to the 102-inch-diameter aft structural ring.

The forward removable panel extends from the forward intercostal to the hatch bulkhead. This panel is 6 inches above the remainder of the floor to clear the EC/LS ducting. The forward right cover is also cut around the semi-circular duct. Additional side edge members reinforce this panel. Attachment is to the forward intercostal and the hatch bulkhead.

A common set of secondary structural components comprises the ceiling structure inside the module. The sortie RAM and the RSM each have two utility tunnels 44 inches from the Z centerline and 36 inches from the X centerline plus a single tunnel on the Z centerline that is 24 inches wide and 70 inches from the X centerline. The RSM also has four sleeping compartments and personal equipment storage areas.

Typical secondary structure includes that used to mount external subsystem equipment such as the N_2 bottles for the EC/LS subsystem (which are mounted to the forward primary end ring) and the mating ring on the docking adapter on both the sortie RAM and the RSMs. Each of these bottles is individually truss mounted. Other subsystem equipment such as the water sublimator, thermal storage elements, and freon control valves are platform mounted and attached to the end rings and the docking adapter ring.

Environment Protection

The radiator/meteoroid bumper is made from a sandwich of 0.016-inch outer and 0.010-inch inner aluminum skins bonded to a high-temperature polyurethane foam core. The radiator/bumper panels cover the cylindrical portion of the module and are split into sets of eight 45-degree sections. Each panel contains 15 fluid passages installed longitudinally; four of these are integral with an I-shaped extruded stiffener and the others in a D-shaped extrusion bonded within the sandwich. The fluid passages are connected at the ends of the panels in a radial direction. These connections are made

through a valving system that controls the fluid flow in the eight panels. The panels are about 5.4 by 9 feet and are attached to the sidewall at both ends through hinge fittings that allow the panel to expand or contract under temperature variations.

A similar system is used for the auxiliary radiator over the subsystem tanks on the forward end of the module.

Environmental protection of the conical bulkhead, the aft docking adapter, and the GN_2 bottles uses the same sandwich construction as the cylindrical section, but without the radiator tubes.

Access covers are made in eight sections and are attached to the cylindrical section at the kick rings with slip joints. These covers may be removed to expose the radiator manifold and the hoist fitting attachments. Other access panels on the cylindrical section are removed to expose the ground handling and transportation fittings.

The entire surface area of the module with the exception of the docking interface is covered with 45 layers of SuperFloc insulation. The insulation is supported on fiberglass clips and attached to the bulkheads and the cylindrical sidewall by non-metallic fasteners.

RAM/Orbiter Attachment Fittings

The attachment fitting concept selected for RAM payload carrier is a five-point reaction statically determinate system. The five fittings on the orbiter were assumed to be of ball or trunion mount form located 93 inches from the Y-Z centerline and 25 inches above the Y-Y axis. The fittings are three tripod types (only one of which reacts the longitudinal load) and two simple A-frames that only react lateral loads.

Because the RSM is never in the orbiter without another module, the only RSM attachment fittings are the two tripod fittings at the forward +Y and -Y and an A-frame fitting at the forward -Z position. A beam is used to accept the local moment induced by the longitudinal load and to react this load at the two end rings. The outer flange of this I-shaped beam is welded into the cylindrical side wall, forming a splice joint for the machined panels. The beam is 12 inches deep at the load application location and tapers to 8 inches deep at the forward end and 4 inches at the aft end. An integral blade is machined on the surface of the outer flange of the beam and is used to attach the machined link that forms the third leg of the tripod fitting. Each of the tripod fittings is made from a machined steel A-frame and a machined link as the third leg. This link is attached to the A-frame through a simple clevis and to the upstanding blade of the beam through a knuckle or double clevis attachment. There is also a small beam placed at the -Y location. This beam gives symmetry to the cylindrical structure and provides a structural tie for the orbiter fittings, which will induce small loads in the longitudinal direction.

Crew Mobility/Stability Aids

Crew mobility/stability aids are required to assist the crewmen in performing operations and maintenance tasks on subsystems and experiments. These tasks include such things as hatch operation, experiment setup, reconfiguration of the RSM for various mission phases, wall and equipment access, and crew coordinated activities. These crew aids can be fixed or portable and will include hand rails, foot restraints, and tether attach brackets. The specific location of these aids will be determined after a detailed crew task analysis to indicate heavy traffic or task loading areas. Representative hand hold, hand rail and leg rail mobility and stability aids are shown in Figure 3-11.

The general arrangement and orientation of RSM interior equipment indicate that heavy traffic or task loading occurs at the various work stations. The primary restraint is an open metal triangular grid network in the 1-g floor position, providing capability for a compatible shoe restraint attachment of discreet locations throughout the floor area. The Astrogrid floor and the companion Astrogrid shoe restraint are shown in Figure 3-12. The grid floor is located in the center 60 inches of the module. This floor will replace sections of the 1-inch honeycomb panel.

Hand holds and rails may be attached to equipment mounting structure or directly to the cylindrical sidewalls or bulkheads. The forces imposed by crewmen using these restraints are in the low hundreds of pounds and pose no significant structural problems. The locations of these restraints are not critical to the structure; the waffle-stiffened sidewall and the longitudinally stiffened conical bulkhead can accept these low loads at any location.

3.1.2.3 Environmental Control/Life Support (EC/LS) Subsystem. The EC/LS subsystem provides the same functions shown in Figure 3-13 for the sortie RAM except that it supports a payload crew size of six instead of two. The overall EC/LS schematic for RSM is identical to sortie RAM; however, the weight, volume, and power usage differs due to increased capability required to support six payload crewmen (Figure 3-32 and Table 3-7).

Gaseous Storage Assembly

The gaseous storage assembly consists of the tankage to store nitrogen for module repressurization and leakage. Oxygen storage is integrated with the EPS reactant storage. Each nitrogen tank is 25.3 inches in diameter, weighs 92 pounds, is made of titanium, and can store 60.5 pounds of nitrogen at 3100 psia.

Atmosphere Revitalization Assembly

The atmosphere revitalization assembly circulates cabin atmosphere through various processing units that remove particulate matter and debris, odor, carbon dioxide,

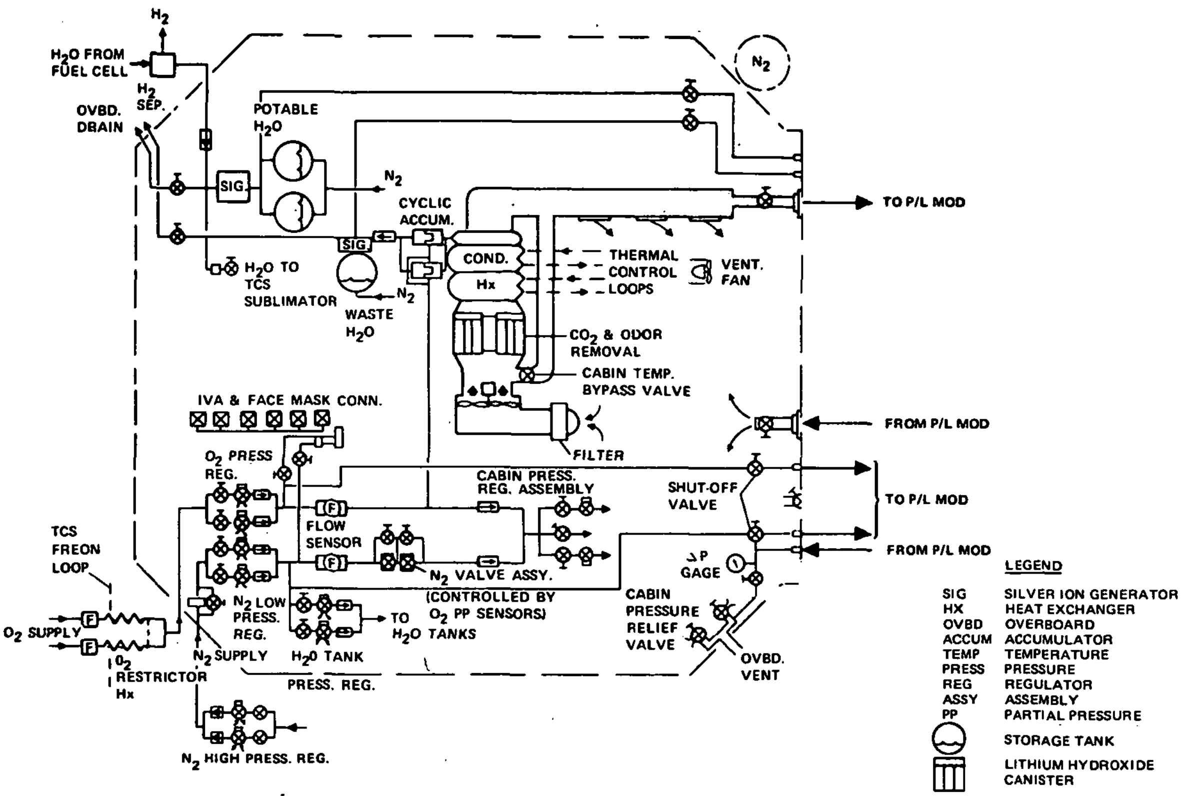


Figure 3-32. RSM EC/LS Subsystem Schematic

Table 3-7. RSM EC/LS Subsystem Physical Characteristics

Function	Weight (lb)	Volume (cu ft)	Power (Watts)
Atmospheric Storage	552	29.0	
Atmosphere Revitalization	220	12.0	270
Pressure Control	101	0.6	
Water Management	135	16.3	
Special Life Support	12	0.2	10
Consummables (not including O_2)	448	8.8	
Totals	1468	66.9	280

water vapor, and heat energy to maintain the atmosphere composition and temperature within specified limits. Composition of the atmosphere is maintained in conjunction with the atmosphere pressure control assembly.

A filter and debris trap is provided to remove particulate matter in the atmosphere and is replaced when the pressure drop indicates a loaded filter. Downstream of the filter, two fans in parallel, each with check valves, circulate the atmosphere through the assembly. Only one fan operates at a time. Lithium hydroxide is used for carbon dioxide removal and activated charcoal for odor and trace gas removal. Each lithium hydroxide canister is sized for a two manday capacity and is designed to be alternately replaced. A condensing heat exchanger provides humidity control. The condensate is collected in cyclic accumulators and pumped to the waste water storage tanks.

The revitalized cabin atmosphere flows through the return duct network, which distributes the air to provide ventilation. To meet the 20-to-50-fpm ventilation requirements, portable ventilation fans are provided at various locations within the module.

The air passing through the condensing heat exchanger is controlled by a bypass to maintain the cabin temperature at a selected value between 65 and 85°F.

Pressure Control Assembly

The pressure control assembly maintains the pressurized volume at 14.7 psia, supplies gaseous oxygen and nitrogen for repressurization and for emergency use, and supplies oxygen gas to the cyclic accumulators and nitrogen gas to the water storage tanks. The RSM contains provisions for supplying and controlling the atmosphere in the RAM payload module.

Cabin atmosphere is maintained at 14.7 psia by controlling the oxygen partial pressure between 3.0 and 3.4 psia and supplying nitrogen gas to make up the balance to achieve the selected cabin pressure. The partial pressure control opens when the oxygen partial pressure is 3.4 psia or above, permitting nitrogen to flow to the cabin pressure regulator until a total cabin pressure of 14.7 psia is reached. When the oxygen partial pressure drops to 3.1 psia, the partial pressure control closes to permit only oxygen to flow into the cabin.

Repressurization, if required, is accomplished by the cabin pressure regulator assembly, which is manually activated by opening the shutoff valves. Positive and negative pressure relief is provided.

Water Management Assembly

The water management assembly prevents bacteria buildup in the water system, provides storage of fuel-cell-generated water and condensate from humidity removal unit(s), and supplies water for the sublimator in the thermal control subsystem. Water

generated by the fuel cell flows through a hydrogen gas separator and a silver ion resin bed to keep it in sterile condition for storage.

Special Life Support Assembly

The special life support assembly is composed of two subassemblies that provide the emergency functions of fire detection and IVA support.

Fire detection is accomplished by a condensate nuclei counter in each module located in the heat exchanger duct system. Since all materials emit large amounts of particles when materials are approaching ignition temperatures, incipient fire hazards are detected by an increased particle count.

Connections for six IVA umbilicals are required. Support is limited to purge flow of oxygen to IVA suits in the event of contingency depressurized or contaminated cabin operations. Oxygen flow is activated manually.

3.1.2.4 Electrical Power. The electrical power subsystem (EPS) provides electrical energy and the associated conditioning and distribution for RSM subsystems and the RAM payload module/RAM pallet. It provides a capacity based on average and peak power demands of the RSM subsystems and the payload for a specified mission duration and delivers power of a type and quality consistent with the load requirements.

Power Generation

The primary power source is a single fuel cell of the type and capacity under development for the shuttle program. While fuel cell characteristics are contingent upon the shuttle fuel cell development program, the present design calls for 7 kW average power output and a peaking capability of 10 kW for 0.1 hour. The fuel cell output voltage will be 24 to 32 volts, with a minimum operational life design goal of 2000 hours. Fuel cell power is used throughout the RSM mission from liftoff to touchdown. For contingency purposes, there are redundant paths available for power from the shuttle.

Fuel cell purging is required. This occurs approximately once a day, with each purge lasting about five minutes. The quantity of fuel purged is negligible (< 0.5 percent) assuming a fuel cell reactant purity of > 99.995 percent by volume for the oxygen reactant. Hydrogen reactant purity of 99.95 percent results in < 0.1 pound H_2 purging for 1000 kW-hr.

Fuel-cell water product disposal/storage is a function of the EC/LS subsystem; approximately 0.85 pound of water is produced for each kW-hr of energy generated. Fuel-cell waste heat removal and temperature control are the responsibility of the thermal control subsystem. Waste heat rejection rates for the fuel cell vary with power plant design. Two fuel cell designs are under evaluation for the shuttle program: the

electrolyte capillar matrix type (Pratt and Whitney) and the solid polymer electrolyte (General Electric). Typical heat rejection requirements as a function of power level are shown in Figure 3-33.

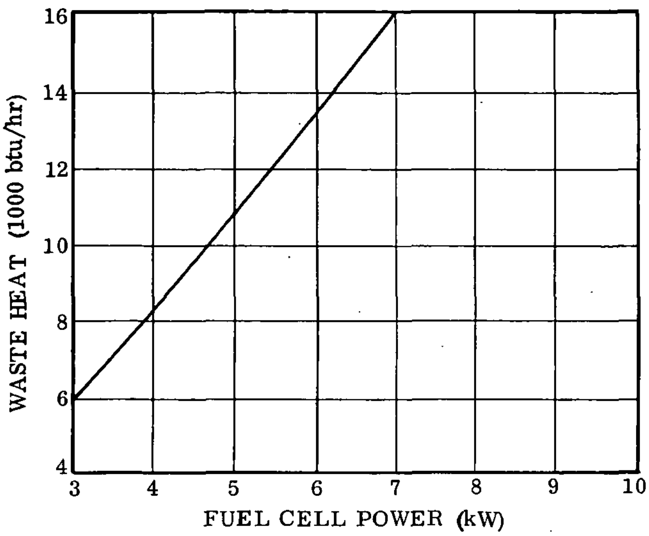


Figure 3-33. Fuel Cell Waste Heat

Reactants are stored in cryogenic tanks of a common design with the shuttle. Two cryogenic oxygen tanks and three cryogenic hydrogen tanks are included to provide a total energy capacity of 1034 kW-hr. EC/LS requirements for oxygen consumption (i.e., metabolic, leakage, repressurization, and IVA contingency) are also provided by the EPS cryogenic oxygen tanks. For 30-day mission, the larger quantity of cryogenic reactant storage required is provided by an addition of four oxygen tanks and six hydrogen tanks (the additional tanks, however, are located on the RAM payload module). Additionally, cryogenic tanks (chargeable to RAM) are added to the shuttle to provide the additional 23 days of shuttle support required; these tanks are added in the OMS area of the shuttle cargo bay.

Distribution, Conditioning and Control

The distribution concept employs spacecraft-proven technology of 28 vdc and 115v/200 vac, 400 Hz distribution. Circuit protection and switching design is based on space shuttle technology and uses solid-state power controllers for loads up to ten amperes. For larger loads, hybrid power controllers are used. These units use solid-state elements for control and protection and electromechanical elements for power switching.

The EPS provides three independent power channels (Figure 3-34): a main bus and two essential (emergency) buses. The main bus powers all normal operations including an experiment bus, and the essential buses satisfy the requirement to sustain two failures. The electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contractors. The two essential buses are powered from the shuttle. Provisions are included to interface with an attached RAM pallet while maintaining the capability to sustain two failures for all elements.

A generally centralized power conditioning concept is used because it was demonstrated to be more cost effective and require less weight and volume. Conditioning consists of dc voltage regulation and dc-to-ac conversion. Local power conditioning with the load equipment is assumed for the nonstandard power characteristics. The larger

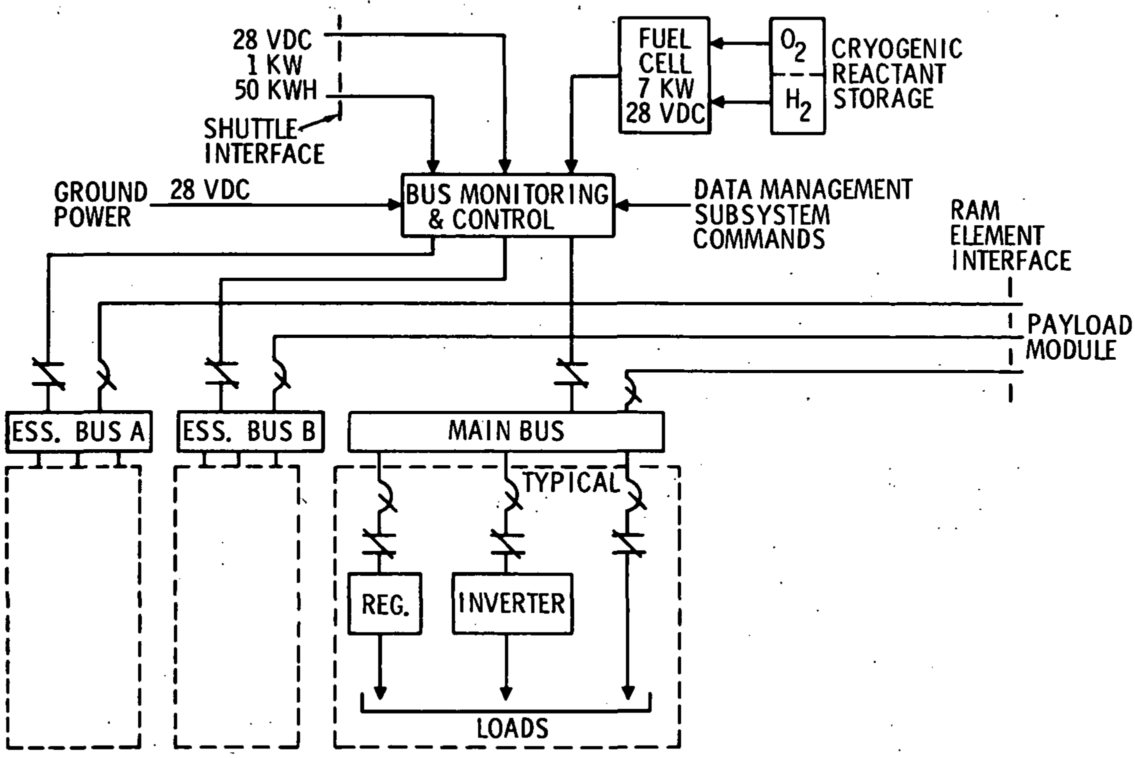


Figure 3-34. RSM Electrical Power Subsystem Schematic

conditioning equipment is either flight qualified or flight proven. The 1500 W regulator is a Skylab design and the 1250 va inverter is based on an Apollo design.

Lighting

General area illumination is provided by fluorescent lights, with spot or high-intensity lighting by incandescent lights. Emergency lighting uses independent circuits with independent fixtures in each compartment.

In work areas, the general area lighting is arranged so that lights may be dimmed to conserve energy when activity is reduced for extended periods. A further consideration is changing requirements in work or experiment areas. When work is shifted from one area to another, lights are dimmed in the first area and turned up to full brilliance in the second. Utility outlets are provided for portable lights and other tools.

Auxiliary Power Generation

No auxiliary power is required or provided within RSM.

3.1.2.5 Habitability. Habitability requirements for RSMs provide crew needs, including personnel equipment, furnishings, hygiene and waste, general equipment, EVA, airlock, and emergency and survival equipment and food.

Identification of these requirements for later-capability sortie payloads is shown in Figure 3-35. Implementation of the principal requirements is shown in Figure 3-36.

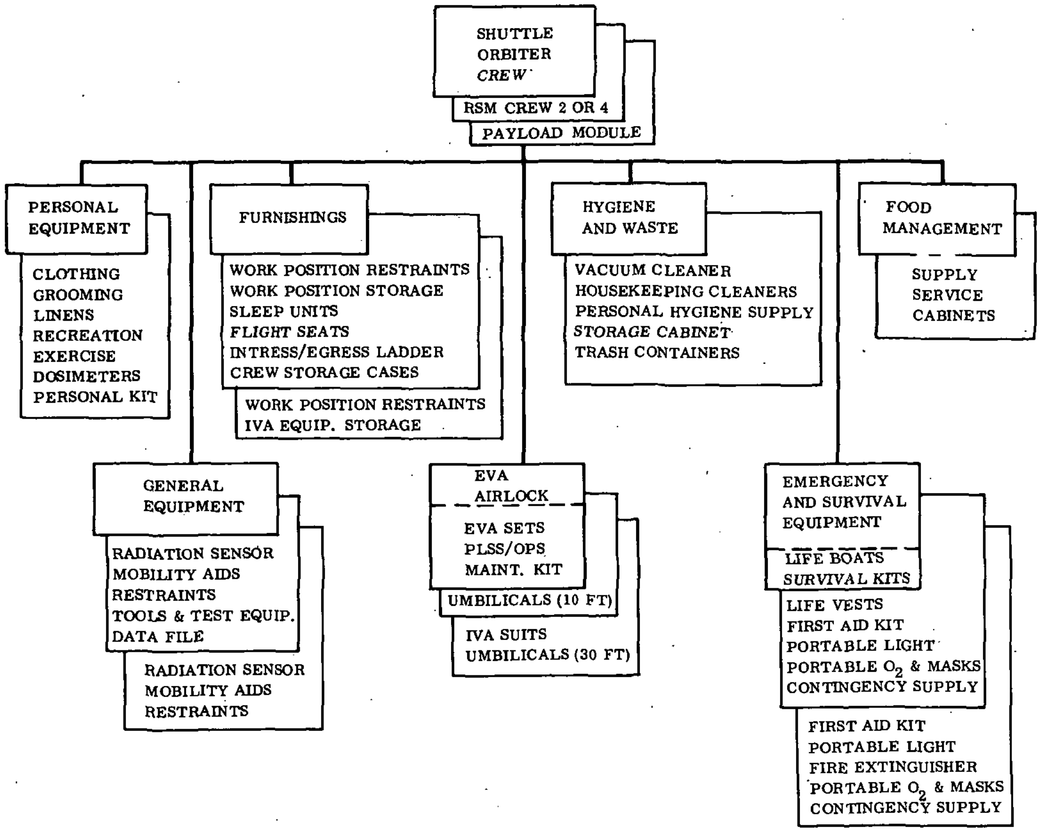


Figure 3-35. Requirement for Habitability Provisions for RAM Support and Payload Modules

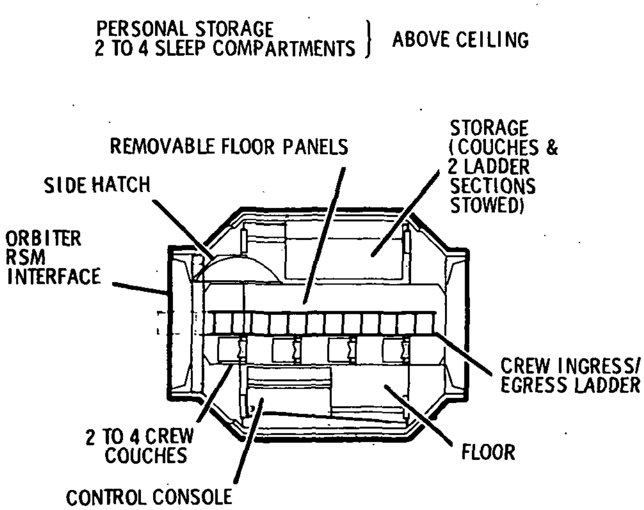


Figure 3-36. RSM Habitability Provisions

The RSM provides the capability to expand the number of payload crewmen from the two used with sortie RAM to a maximum of six (2+2+4). The RSM contains living and working provisions for the payload crewmen (except for hygiene and food management facilities, which are provided for all payload crewmen by the shuttle orbiter). This is accomplished by providing launch/entry couches and sleeping compartments. The couches are stowed during orbital operations. The ladder provided for crew ingress and emergency egress on the launch pad is stored during orbital and entry flight phases. The hygiene

facilities in the orbiter consist of a lavatory, urinal, and toilet. Food management facilities are those necessary for food preparation and eating.

An inline arrangement of couches was selected based on the results of a trade study in which simulated emergency egress configurations were evaluated. The ladder is located adjacent to the seat backrests about at a crewman's shoulder position. The ladder orientation is with the rungs parallel to the RSM floor.

Two payload crewmen continue to be accommodated by the shuttle orbiter for launch/entry seating and sleeping. All payload crewmen use the orbiter galley and hygiene provisions.

Since RSMs are always flown with RAM payload modules attached, habitability provisions for RAM payload modules attached to RSMs are also shown in Figure 3-35. Habitability provisions for RAM payload modules attached to space stations are described in Paragraph 3.1.3.5.

3.1.2.6 Communications. The orbiter provides all communication support for the RSM by sharing its VHF/TDRS links (voice, low rate telemetry and command) and S-band links to the ground network (1 Mbps digital data transmission), as illustrated in Figure 3-37.

3.1.2.7 Data Management and Onboard Checkout Subsystems. The basic data-handling approach uses permanent digital magnetic tape and onboard data storage. Data is recorded with volumes ranging from 2×10^7 to 2.3×10^{12} bits per mission and at rates as high as 50 Mbps. Reels of tape carried range from 2 to 35, 6 of which are carried in the RSM. One 14-inch reel of 1-inch tape can store 62 Gb of data and accommodate nearly 58 percent of the payloads. A limited number of payloads require near-real-time transmission of information with rates up to 1 Mbps.

Data management subsystem (DMS) major components are located in the RSM (Figure 3-39). An upgraded version of the Skylab tape recorder (67 Mbps, 28 tracks, 20 kb/inch/track) is provided for digital recording. A high-rate switching and multiplex unit is hardwired to wideband experiment digital and the orbiter S-band system.

A full multiplex data acquisition and command distribution system is used to transfer signals between subsystems, experiments, the orbiter, and ground prelaunch equipment. Computer control of the multiplex system is via computer interface units. Digital interface units (DIUs) receive and transmit low-rate information over the full multiplex wire, decode instructions into functional commands, and provide a buffer for data generated by and sent to experiment sensors. Interface terminals, a low-rate formatter, and command decoders tie in to the orbiter communication link for telemetry and command and the orbiter guidance, navigation, and control IMU to obtain information for astronomy experiment attitude control. Typically, as many as 1000 signals are associated with the subsystems and experiments. Seven DIUs are used to provide redundancy.

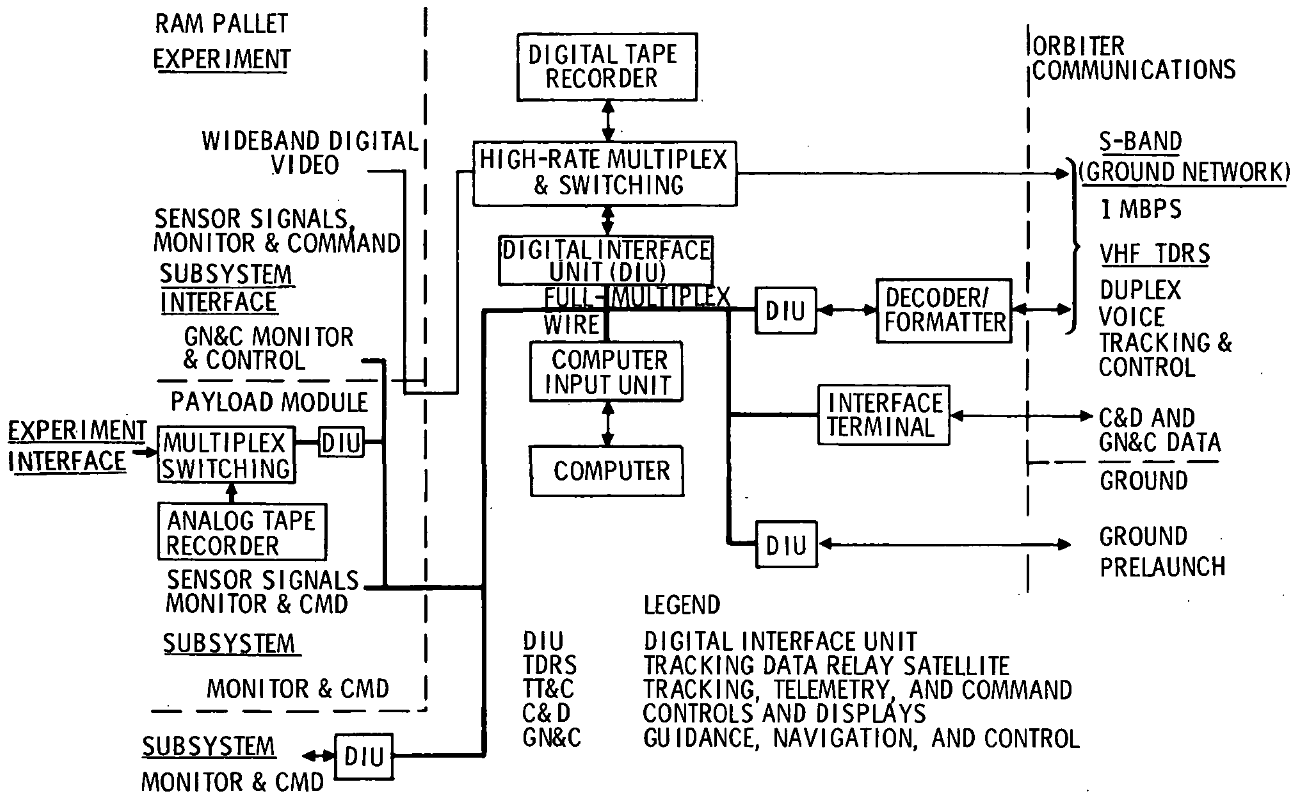


Figure 3-37. RSM CDMS

Control, monitor, and automatic checkout of all subsystems and experiments is by a centralized computer configuration. Floating-point hardware is used and three computers provide redundancy. Software implementation features a modular structure under control of a hybrid executive. A separate software package is used for experiments and generalized for all subsystems. A high-order language selected from those currently under development is proposed to reduce coding effort and provide simpler debugging, easier verification, and better documentation.

The onboard checkout subsystem (OCS) for the RSM is an autonomous, flexible, job-oriented system that performs highly organized, repetitive functions (such as status monitoring) automatically while permitting crew participation in those functions performed periodically or on an as-needed basis (such as fault isolation, redundancy switching, and checkout). This versatility in applying degrees of automation to suit functional need is further extended to include the differences between the RSM subsystems (which are relatively stable and lend themselves to automation) and the payload experimental equipment (which is continually varied and does not).

The onboard checkout system uses the communication and data management subsystem (CDMS) data processor, data distribution system, and interfacing units. It supplies a stimuli generator to activate subsystems for checkout and fault isolation. It also provides a caution and warning (C&W) logic module, which monitors caution and warning conditions aboard RSM. This function is performed concurrent with, but independent

of, other checkout functions by the OCS. C&W signals are generated by the logic module and distributed by hardware to the visual display and aural alarms located in all habitable locations aboard the RSM and to the orbiter. Signals are also generated and transmitted by hardwire to the computer for automatic response to the detected condition.

The C&W advises the crew members that there has been a malfunction that may be hazardous to the crew, the classification of the hazard (emergency, caution, or warning), and the identity of the specific hazard (e.g., temperature high, temperature low, etc.). The major criteria on which the system concept was developed are the need for a uniform man/machine interface and the need for an onboard autonomous system to provide absolute monitoring of physical life-critical parameters. Any out-of-tolerance conditions of these parameters would cause a potential crew hazard situation, and indication of these hazards must be immediately transmitted to the crew. There are two emergency conditions: fire and rapid pressure loss. When either of these conditions occurs, the C&W system will indicate the nature of the emergency audibly and visually. The emergency, warning, and caution audible indications are distinctly different, whereas the emergency and warning visual indications are identical.

The RSM/orbiter interface allows C&W display and alarms from the RSM to be seen in the orbiter and control responses from the orbiter (both cockpit and aft station) to direct subsystems in the RSM. Such capability ensures crew cognizance of all C&W situations and response capability during all mission phases, whether RSM is manned or unmanned (such as during ascent and entry). From the orbiter commander's panel, the only control available is to initiate response to a fire in the RSM/RAM payload module. All categories of C&W situation information are displayed and controls may be initiated at the orbiter aft station (third station). Typically, this station will be used to verify that RSM is safe to enter (all subsystems functioning normally, atmosphere proper, etc.) prior to initiation of on-orbit operations. Figure 3-38 is a simplified diagram illustrating the RSM/orbiter interface and operational details of the overall C&W function.

OCS is also used during prelaunch checkout. It controls and monitors the activated RAM subsystems during the launch readiness phase and during the boost and ascent phase.

3.1.2.8 Control and Display (C&D) Subsystem. The C&D subsystem provides the major man/machine interface to effectively control and manage payload experiments and RAM subsystems. The crew requires access to information in a form that facilitates their decision processes. This access must be capable of being used for several functions at the same time or at different phases of the mission.

The major functions provided by the C&D subsystem are to:

a. Provide a two-man C&D console for centralized management of subsystems and selected experiments, as desired.

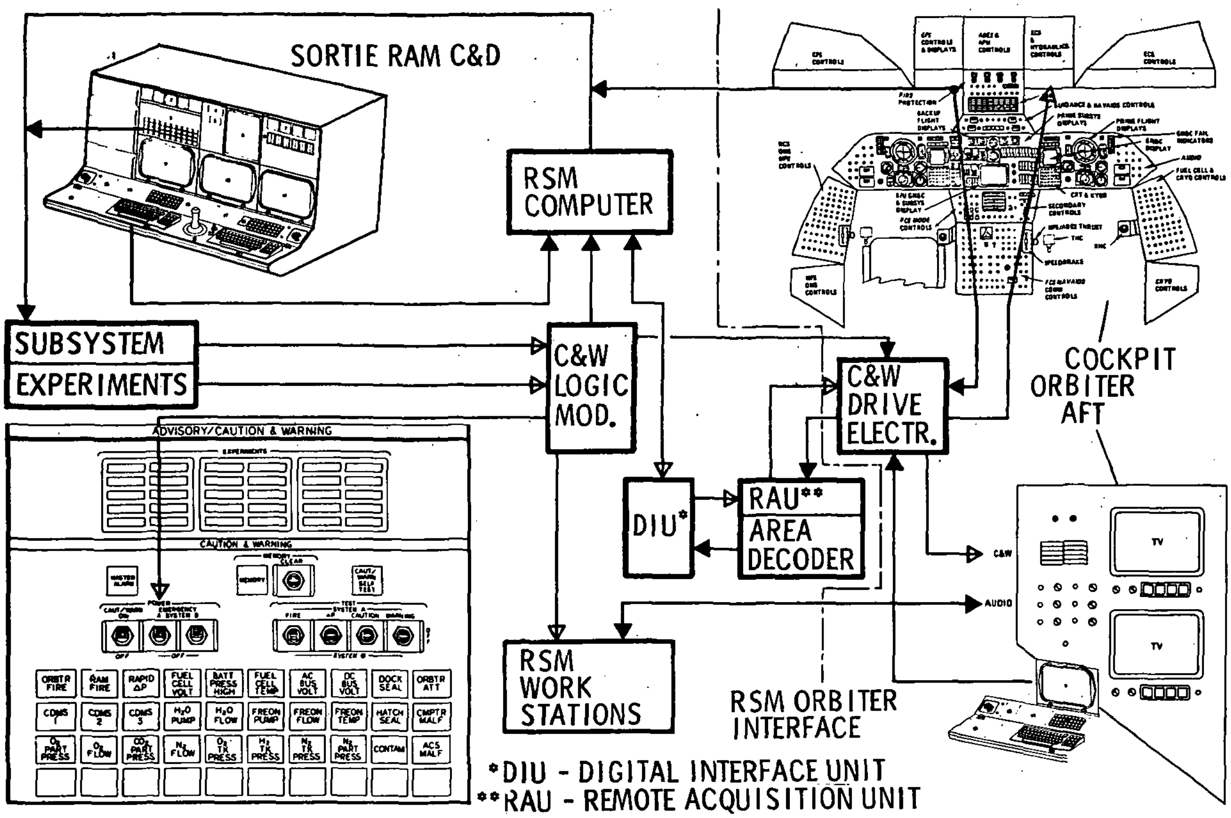


Figure 3-38. RSM/Shuttle C&W Interface

b. Provide capability for experiment-dedicated unique C&D.

c. Provide caution and warning terminals indicating C&W situations.

d. Provide audio communications.

e. Provide for closed-circuit television.

Control and Display Console

The centralized management of selected experiment and subsystem functions is provided by the data and subsystem console located in the RSM. The console provides an optimum mix of conventional dedicated C&D and integrated, software-oriented, multipurpose C&D station, weighs 573 pounds, has a volume of 29 cubic feet, and consumes 540 Watts of power. Provisions are included to accept standard-panel-size, dedicated-experiment C&D, as shown in Figure 3-39.

The data management computer provides the console with information through its interface with the subsystems and experiment payload. Digital interface units provide the interface to the data management computer via a multiplex bus allowing payload and subsystem C&D to be handled by software.

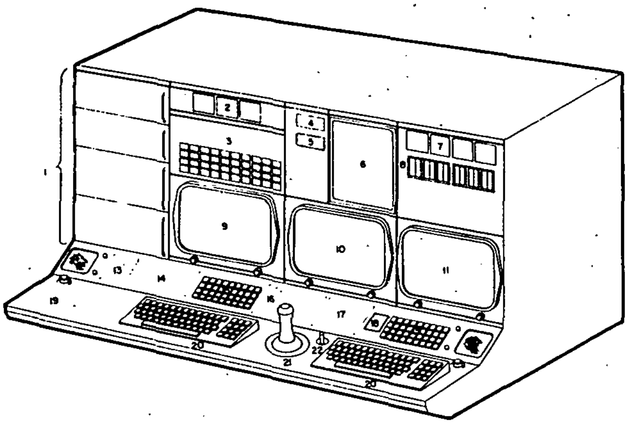


Figure 3-39. C&D Console

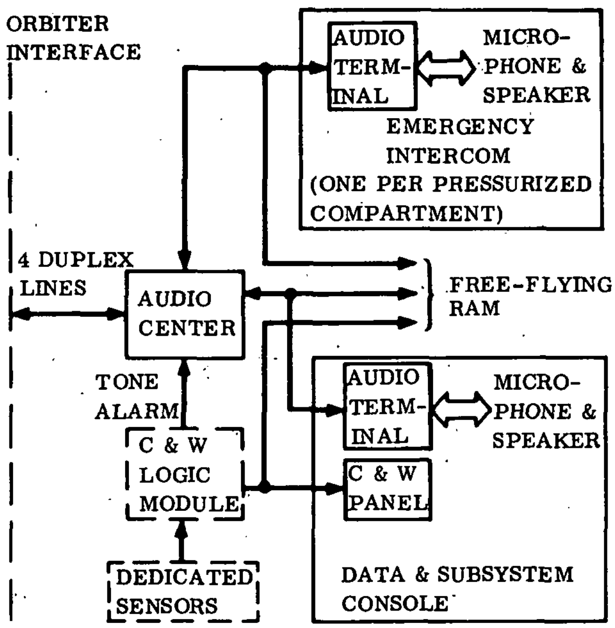


Figure 3-40. RSM Audio and C&W Distribution

Audio Distribution

The audio distribution terminals use headsets and fixed speakers or microphones. Headset voice functions include duplex voice communications between payload crew members and orbiter crew members as well as between payload crew members themselves. Duplex voice communication with the ground is routed to the orbiter for transmission. The fixed speaker/microphone functions include simplex (talk or listen) voice communication between payload crew memmembers and orbiter crew members as well as between crew members themselves. The emergency audio station consists of a speaker/microphone that provides simplex voice communication between the RSM and the orbiter via the emergency intercom bus. The interface with the caution and warning logic module for aural alarms is as shown in Figure 3-40.

Caution and Warning (C&W) Panels

C&W panels located on the data and subsystem console provide for display of C&W situation information. The master alarm and C&W indicators are activated when any emergency, caution, or warning situation is detected. Manual intervention is necessary to reset C&W indicators following corrective action.

Closed Circuit Television (CCTV)

Control and display is provided by the RSM for CCTV cameras located to view equipment operation on the RAM pallet. The CCTV cameras and associated floodlights are located on the orbiter manipulator arms. An interface between the orbiter and the RSM will allow TV video to be displayed on the C&D console. The same interface will allow pan, tilt, and zoom of the CCTV cameras.

3.1.2.9 Guidance, Navigation and Control (GN&C) Subsystem. There are no GN&C provisions within the RSM except for the computational functions associated with GN&C performed in the digital processor. For these payloads requiring stabilization and attitude control, the basic capabilities of the shuttle are used where they satisfy the payload stabilization and control requirements. For some payloads (Astronomy discipline), however, the driving performance requirement is all-attitude pointing to 0.5 arc-sec, which is well beyond the capability of the shuttle orbiter. This capability (Figure 3-41) is provided by experiment integration equipment mounted on the RAM pallet and consisting of a payload gimbaling assembly, fixed-head star trackers, a rate gyro package, and CMGs.

3.1.2.10 Thermal Control Subsystem (TCS). The RSM heat transport system (Figure 3-42) is similar to that of the sortie RAM. The RSM provides total thermal control for advanced sortie missions, including the RAM payload modules. To accomplish the total task, the TCS uses radiators located on the RAM payload module and must supply cold water for the RAM payload module cold plates and cabin air heat exchanger. Cabin

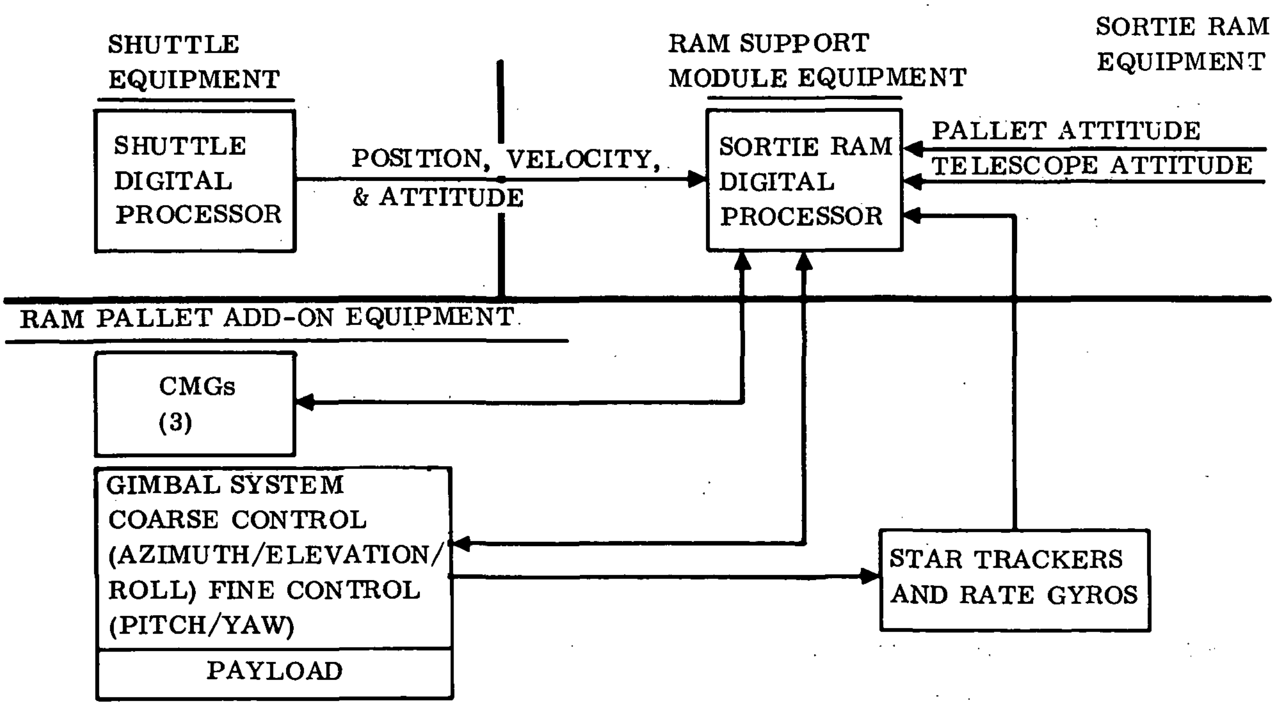


Figure 3-41. RSM GN&C Representation

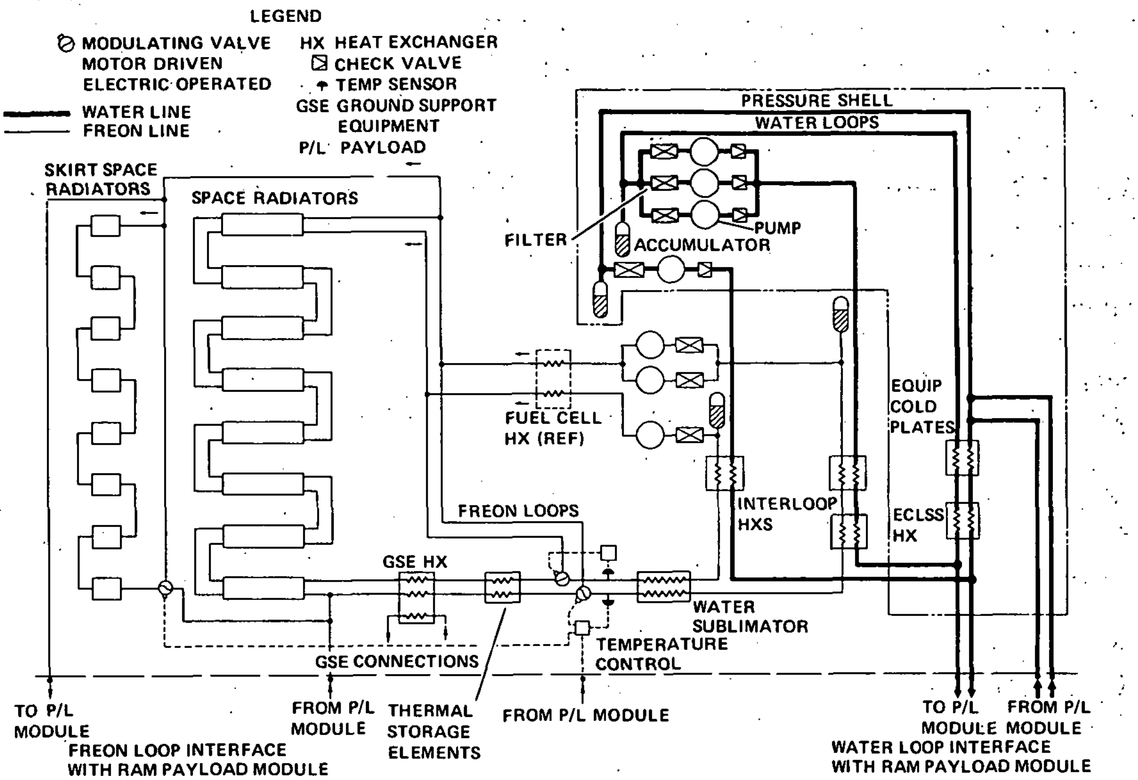


Figure 3-42. RSM Thermal Control Subsystem Schematic

air cooling requirements resulted in placing a cabin air heat exchanger in the RAM payload module. As noted in Figure 3-35, the increased loads also resulted in another water pump and another intercooler. Also shown in the figure is the requirement for the freon and water coolant interfaces with the RAM payload module.

Water is used as the heat transfer fluid within habitable compartments to meet the requirements of nontoxicity and nonflammability. The water loop interfaces with the freon 21 heat transport fluid through the interloop heat exchanger. The freon loop is located outside the habitable compartments and transfers heat to the space radiator for rejection to space. Freon is used since the radiator temperature can be well below the freezing point for water in some cases. A bypass valve around the radiator regulates the freon temperature to 35°F and provides control for variations in internal and external loads. For closed-shuttle-door operation and transient peak heating periods, a water sublimator and thermal storage element (TSE) are provided. An interface heat exchanger (GSE Hx) receiving coolant from ground support equipment is used during prelaunch and postlanding operations. The TCS interfaces with the EC/LS subsystem at the air-to-liquid heat exchangers. Cabin sensible and latent loads are absorbed at this point by the TCS. Freon is used to warm the cabin oxygen supply.

There are two completely independent systems, with each system capable of carrying the entire cooling load and thereby providing redundancy in case of component failure.

There are three pumps in the primary water system. Two must be active during maximum cooling requirements and the third is a standby pump. The primary freon loop has one active and one standby pump. The system satisfies the failure modes and effects analysis criteria. Radiators on the skirt and RAM payload module do not contain redundant coolant loops, since the experiments can be powered-down in the event of failures to reduce cooling requirements to within the capability of basic RSM radiators. The basic components should be available or under development from shuttle or other space programs.

The selected radiator configuration has 3/16-inch inner diameter longitudinal tubes spaced eight inches apart and attached to the 0.016-inch-thick outer meteoroid shield. There are eight redundant tubes on each panel interspaced between the active tubes. A RAM element radiator consists of eight series panels around the circumference of the vehicle, and each panel consists of eight parallel tubes. A 5-mil Teflon-silver coating was selected for the RAM radiators. For sortie missions, Teflon-silver is about 10 percent better than the usual space white paint Z-93 and does not require radiator panel bypass valves. The degraded coating characteristics for Teflon-silver used in the RSM performance analysis are 0.09 for absorptance and 0.80 for emissivity. Radiator performance depends on the surface coating, RAM/orbiter configuration, orbit, and vehicle orientation. Net radiator heat rejection for various design conditions are shown in Figure 3-43. All payloads can reject the required cooling load and maintain the cabin temperature within the 65°F range. Some payloads require water boiling to supplement the radiator.

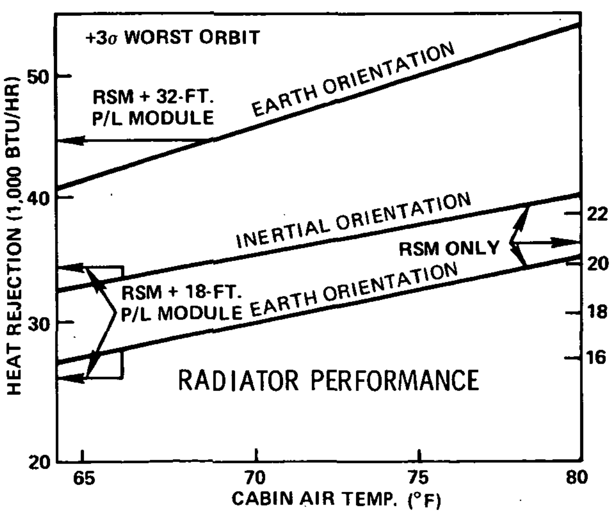


Figure 3-43. RSM Radiator Performance

The heat-rejection capability of the RSM when used in combination with either an 18-foot or a 32-foot RAM payload module for three orientations while maintaining a cabin temperature of 65°F is given in Table 3-8.

3.1.2.11 Mass Properties. The estimated mass properties of the basic RSM appear in Table 3-9. The predicted weights are based on the design and subsystems data presented in Paragraphs 3.1.2.1 through 3.1.2.10. Allowances have been included in the weight breakdown for installation hardware and other features not defined in the design drawings and subsystem schematics. The weight breakdown format complies with MIL-M-38310A.

The weight of the RSM shown in Table 3-9 represents a factory-complete article without subsystem add-ons, personnel and gear, residuals, reserves, or expendables. Crew size for the RSM is two to four, depending on payload requirements. (An

Table 3-8. RSM Plus Payload Module Heat Rejection Capability

Orientation	RSM + 18-ft RAM Payload Module (Btu/hr)		RSM + 32-ft RAM Payload Module (Btu/hr)	
	+3σ Heating	Nominal Heating	+3σ Heating	Nominal Heating
Earth	27,900	30,400	41,800	44,300
Inertial	34,100	36,600	50,700	53,200
Away from Earth	35,900	38,400	53,600	56,100

additional 2 + 2 crew chargeable to the orbiter complements the crew in the RSM.) Mission duration is up to seven days.

3.1.2.12 User Provisions. The provisions and capabilities in the RSM for the performance and support of experiments is presented in Table 3-10. The net experiment support capability is derived by subtracting resource and subsystem requirements from the total RSM capability. Electrical power is supplied by one fuel cell with a capacity of 7 kW average and a peak capacity of 10 kW for 0.1 hour. A portion of the 7 kW average power (4.4 kW) is available as regulated dc and ac voltage in the quantities shown in the table for experiment operations. Six tapes of 6.2×10^{10} bits storage capacity each are carried in the RSM. Communications, guidance, navigation, and control are supplied by the shuttle. The thermal control subsystem maintains the cold-plate temperature from 80 to 95°F for thermal loads of from 0 to 7500 Btu/hr when connected to the 18- or 32-foot RAM payload module. The total heat rejection capability shown is for the module pointed away from earth.

3.1.3 RAM PAYLOAD MODULE

3.1.3.1 Configuration. The RAM payload module is a pressurized RAM evolving from the sortie RAM and is applicable to both sortie and station-attached missions. In sortie missions, it is always attached to an RSM, which is always attached to the shuttle orbiter. Major features of the RAM payload modules are:

a. A 14-foot diameter shell by about 18 or 32 feet in length.

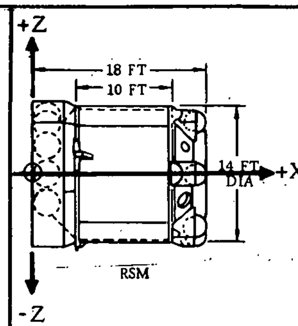
b. An interior arrangement consisting of provisions for easy installation and removal of experiment equipment peculiar to each payload.

c. Provisions for an interface with the RSM or sortie RAM at the forward end of the RAM payload module. The interface permits its crew movement between the RSM or sortie RAM and the RAM payload module.

d. A removable 102-inch-diameter aft domed bulkhead, which can be replaced by special bulkheads capable of supporting internal viewing instruments and large external experiment sensors.

e. A 160-inch-diameter aft flanged ring that provides for the attachment of external sensors or an unpressurized (pallet) RAM for sortie missions.

Table 3-9. Basic* RSM Mass Properties Summary

Subsystems (MIL-M-3810A)	
Structure	3461
Induced Environmental Protection	1382
Docking	475
Prime Power Source	1046
Electrical Conversion and Distribution	301
On-Board Checkout	18
Data Management	320
Displays and Controls	663
Electrical Wiring	423
Atmospheric Control	1077
Thermal Control	990
Life Support	166
Interiors	565
Basic Weight (lb)	10887
Center of Gravity Location (inches from datum on sketch)	
X	93
Y	-4.3
Z	5.6
Mass Moment of Inertia About CG (slug-ft^2)	
I_{XX}	10760
I_{YY}	14740
I_{ZZ}	15190
Product of Inertia About CG (slug-ft^2)	
I_{XY}	384
I_{YZ}	64
I_{XZ}	-1240

*Factory complete condition. Excludes subsystem add-ons, experiments, crew and crew equipment, reserves, residuals, and in-flight losses.

Table 3-10. RSM Support Capabilities

Parameter	Total Capability	Net Capability for Experiments	Explanatory Note
1. Volume (ft^3)	1950	0	29 ft^3 console is located in RSM.
2. Crew size/manhours per day	2 to 4/24 to 48	2 to 4/21.5 to 45.5	Habitability for 2 provided by shuttle, remainder by RSM.
3. Electrical Power Total, unregulated (±15%) 28 vdc ±5%/115 vdc, 400 Hz	 7 kW, 1034 kW-hr	 4.4 kW, 600 kW-hr 1.5 kW/1.25 kva	
4. Data Acquisition: Max. data rate Storage (b/reel/No. of reels)	 67 Mbps $6.2 \times 10^{10}/6$	 67 Mbps $6.2 \times 10^{10}/6$	
5. Control and Display	Includes subsystem dedicated C&D	Payload-dedicated C&D console	
6. Communications Transmission capacity	 1 Mbps peak	 1 Mbps peak	 Shuttle provided
7. Guidance, Navigation, & Control Pointing Accuracy (deg)/ Stability (deg/sec) Position (n. mi.)/velocity (fps)	 ±0.5/±0.03 ±1.0/±10	 ±0.5/±0.03 ±1.0/±10	Shuttle provided
8. Thermal Control Air temp/heat rejection	For 18-ft RAM payload module: 30,400 Btu/hr	70 to 105°F/ 0 to 7500 Btu/hr	Thermal control for RAM payload module + RSM.
Cold plate temp/heat rejection	For 32-ft RAM payload module: 48,000 Btu/hr	80 to 95 °F/ 0 to 7500 Btu/hr	
9. Viewports	Three 12-inch-diameter viewports located at aft 45-deg conical section.	Three 12-inch-diameter viewports located at aft 45-deg conical section.	
10. Feedthroughs	Interconnects provided for utilities.	Interconnects provided for utilities.	

f. For specific station-attached missions, accommodation of experiments in conjunction with a deployable dome attached at the 160-inch diameter (13.33 feet). The deployable dome is pressurizable to provide a shirtsleeve working environment.

g. For some potential station-attached mission, accommodation of an experiment-peculiar module. This configuration requires an interface structural assembly on the +X end of the module identical to that on the -X end.

The RAM payload module is conceived in two basic lengths, with an 8-inch variation between the equivalent module for sortie missions versus station-attached missions. This 8-inch variation results from the necessity to incorporate in the station-attached RAM payload module an 8-inch-long by 102-inch-diameter adapter between the docking adapter and the forward conical bulkhead to ensure compatibility with the shuttle orbiter vehicle payload attachment point. The distance between the shuttle docking adapter interface and the forward payload attachment points in the orbiter cargo bay is a fixed distance of 54 inches; with the 8-inch-long adapter, the RAM payload module is also 54 inches between the docking adapter interface and its forward attachment fittings. The sortie mission RAM payload module does not interface with the orbiter docking adapter, since it is attached to either a RSM or sortie RAM, which interfaces with the orbiter docking adapter and the forward cargo bay attachment points. To minimize the length of the RSM or sortie RAM to RAM payload module combination, the 8-inch by 102-inch-diameter adapter is deleted from the sortie mission RAM payload module. The two sizes are shown in Figure 3-44.

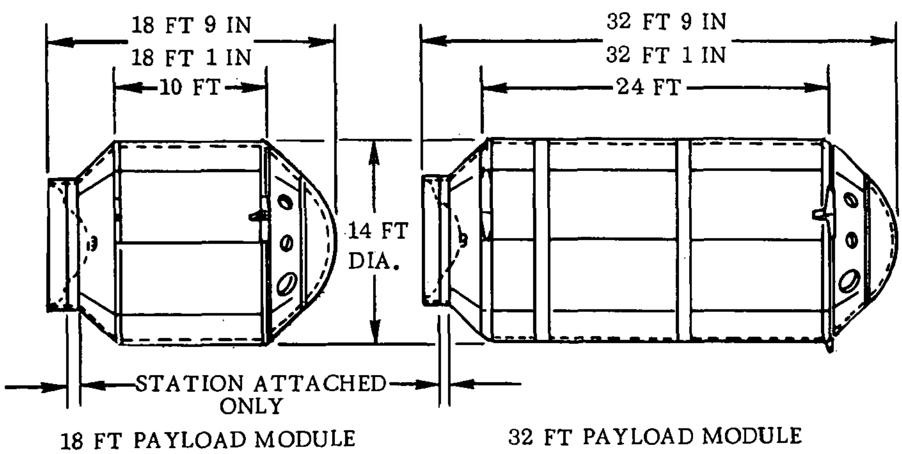


Figure 3-44. RAM Payload Modules

Table 3-11 lists the more pertinent characteristics of the RAM payload modules in their various configurations.

The combination of RSM and RAM payload module increases the scientific experimentation capability over that of the sortie RAM in terms of quantity and scope by the use of a larger crew and in some cases a greater quantity of scientific apparatus.

Sortie Mission RAM Payload Modules

Sortie missions use both versions of the RAM payload modules. The 18-foot length is configured to use the same primary structural assemblies as the sortie RAM; the 32-foot length is structurally identical to the 18-foot length except the constant-diameter sidewall section is 24 feet long in lieu of 10 feet. The 18-foot version is sometimes used with a palletized RAM, but the 32-foot version is not. Figure 3-45 illustrates the 18-foot-long sortie mission RAM payload module. Only minimum subsystems are installed, as the RAM payload module derives subsystem support from the RSM.

Table 3-11. Characteristics — Payload Modules

Parameter	Sortie Missions: 18-ft Basic Configuration*	Sortie Missions: 32-ft Basic Configuration*	Station Attached: 18-ft Basic Configuration*	Station Attached: 32-ft Basic Configuration*
Overall Length	217.0 in. (18.1 ft)	385.0 in. (32.1 ft)	225.0 in. (18.75 ft)	393.0 in. (32.75 ft)
Constant Section Sidewall Length	120.0 in. (10.0 ft)	288.0 in. (24.0 ft)	120.0 in. (10.0 ft)	288.0 in. (24.0 ft)
Internal Diameter, Pressure Shell	160.0 in. (13.33 ft)	160.0 in. (13.33 ft)	160.0 in. (13.33 ft)	160.0 in. (13.33 ft)
External Diameter, Radiator/Meteoroid Bumper	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)
Maximum Diameter	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)	168.0 in. (14.0 ft)
Internal Volume	1910 ft^3	3860 ft^3	1950 ft^3	3900 ft^3
Floor Arrangement	Longitudinal	Longitudinal	Longitudinal	Longitudinal
Support Fittings, Orbiter Attach	2 or 0	2	5	5
Hatches	1 @ 60.0 in. dia.	1 @ 60.0 in. dia.	1 @ 60.0 in. dia.	1 @ 60.0 in. dia.
Viewports	3 @ 12.0 in. dia. Aft Cone 1 @ 6.0 in. dia. Hatch	3 @ 12.0 in. dia. Aft Cone 1 @ 6.0 in. dia. Hatch	3 @ 12.0 in. dia. Aft Cone 1 @ 6.0 in. dia. Hatch	3 @ 12.0 in. dia. Aft Cone 1 @ 6.0 in. dia. Hatch
Crew Complement	2 to 4	2 to 4	2 to 4	2 to 6
Mission Duration	7 Days Nominal	7 Days Nominal	5 Yrs	5 Yrs
Electrical Power System				
Source	RSM Supplied	RSM Supplied	Station Supplied	Station Supplied
Distribution Voltage	28 DC	28 DC	28 DC	28 DC
EC/LSS				
Atmosphere Pressure	14.7 psia; ∂P_{O_2} = 3.1 psia	14.7 psia; ∂P_{O_2} = 3.1 psia	14.7 psia; ∂P_{O_2} = 3.1 psia	14.7 psia; ∂P_{O_2} = 3.1 psia
∂P_{CO_2}	5 mm Hg	5 mm Hg	5 mm Hg	5 mm Hg
Atmosphere Temperature	Selectable 65° to 85°F	Selectable 65° to 85°F	Selectable 65° to 85°F	Selectable 65° to 85°F
CO_2 Removal	RSM	RSM	Station	Station
TCS (Two Loop, Radiator Bypass System)				
External Loop	Freon 21. Extension of RSM Loop	Freon 21. Extension of RSM Loop	Freon 21. Total Independent System	Freon 21. Total Independent System
Internal Loop	H_2O. Extension of RSM Loop	H_2O. Extension of RSM Loop	H_2O. Total Independent System	H_2O. Total Independent System
Equipment Cooling	Cold Plate and Air	Cold Plate and Air	Cold Plate and Air	Cold Plate and Air
Radiator Area	390 ft^2	842 ft^2	390 ft^2	842 ft^2
Cooling Capacity Radiator	11,700 Btu/hr Min.	25,600 Btu/hr Min.	11,300 Btu/hr Min.	24,400 Btu/hr Min.
Ascent/Descent Cooling & Transient Peaks	RSM Function	RSM Function	Sublimator & Thermal Storage	Sublimator & Thermal Storage
Communications	Shuttle Provided Hardline to RSM	Shuttle Provided Hardline to RSM	Station Provided Hardline to Station	Station Provided Hardline to Station
Data Management				
Data Handling	None (in RSM)	None (in RSM)	Station Supported	Station Supported
Onboard Processing	None (in RSM)	None (in RSM)	Limited	Limited
Acquisition & Command Distribution	Full Multiplex	Full Multiplex	Full Multiplex	Full Multiplex
Checkout, Fault Isolation	(RSM DMS)	(RSM DMS)	Integrated into DMS	Integrated into DMS
Controls and Display Console	None	None	None	None
Habitability				
IVA Suits, Umbilicals	4 Suits, 4 Umbilicals	4 Suits, 4 Umbilicals	0	0
IVA Stations	2	2	2	2
Weight, Dry (Without Payload, Add-ons, Expendables)	5798 lb	8744 lb	7367 lb	10,444 lb

* Basic Configuration is with dome type end closure.

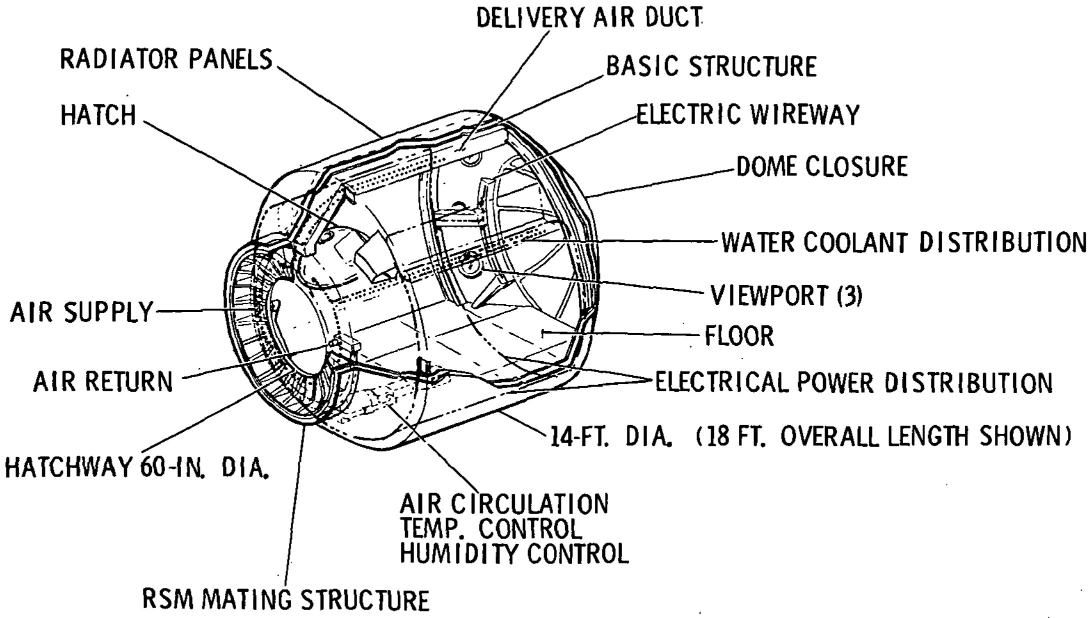


Figure 3-45. Sortie Mission, 18-Foot RAM Payload Module

The module primary structure consists of a 160-inch-diameter waffle skin constant-section cylinder 120 inches long with an 8-inch-deep frame at each end. A 45-degree conic section is attached at each end of the cylinder and truncated by a 102-inch-diameter bolting flange normal to cylinder centerline. The forward conical section is mated to an interface adapter assembly that physically interfaces with the orbiter, RSM, or space station. This adapter assembly is basically a space station docking assembly without the docking frame, attenuator/actuators, hydraulic/air power systems, and associated controls. The conical section at the aft end has a closure dome mating at the 102-inch-diameter attaching ring in the basic configuration. Payload-peculiar bulkheads replace the closure dome for some experiments.

The external surface of the pressure shell is totally covered with meteoroid bumper panels. Those panels over the main constant-diameter section also contain integral fluid lines, which serve as the heat rejection radiator. Two aft orbiter attach fittings are bolted to the extension of the end frame. When used with a palletized RAM, the 18-foot version has all orbiter attach fittings removed.

The internal floor is 46 inches below the horizontal centerline and consists of a fixed section along each wall with removable sections 60 inches wide through the center. For the 18-foot RAM payload module, this arrangement is the same as used in the sortie RAM and is merely extended for the 32-foot length.

Essential air conditioning components are installed below the floor with ducting routed forward, around the interface assembly, and up and across the module along the +Z internal surface. The installation is the same as for the sortie RAM except there are no provisions for LiOH canisters.

An electrical distribution center is located forward on the left side (-Y) in the conical transition area above the IVA control station. This center contains power, control, and data circuits.

The internal thermal control subsystem components consist of a water loop brought through the RSM interface for cold plate temperature control of experiment equipment and then returned to the RSM through the interface.

Cabinets for two IVA suits and three umbilical cords are located on each side of the vehicle in the forward transition cone area. Just above each are the IVA control stations with face masks. The umbilicals plug in at these stations. The left IVA control station and the right suit/umbilical storage is similar to the sortie RAM installation. A cabinet enclosure for housekeeping equipment is located on the forward right-hand side in the conical transition area above the IVA control station. Virtually all of the internal volume above the floor is available for experiment apparatus installation.

Station-Attached RAM Payload Modules

The station-attached missions use both lengths of the RAM payload module. These modules are also derived from the initial sortie RAM and have some slight differences relative to the sortie mission RAM payload modules, primarily in the structure and thermal control system. The structural differences are associated with support within the orbiter bay, while the thermal control system differences stem from the requirement that station-attached modules must provide their own heat-rejection capability. Figure 3-46 illustrates the 32-foot-long basic versions of station-attached RAM payload modules. The 32-foot version is structurally identical to the 18-foot version except that the constant-diameter sidewall section is 24 feet long in lieu of 10 feet. Minimum subsystems are installed in RAM payload module, as it derives most of its subsystem support from the space station.

The module primary structure consists of a 160-inch-diameter waffle skin constant-section cylinder 10- or 24-feet long with an 8-inch-deep end frame at each end. A 45-degree conic section is attached at each end of the cylinder, truncated by a 102-inch-diameter bolting flange normal to the cylinder centerline. The forward end of this structure is mated to an interface adapter assembly with an 8-inch cylindrical adapter. The additional 8-inch length for the station-attached RAM payload modules is to place the forward three orbiter attach fittings at the same location as the fittings on the sortie RAM, RSM, and free-flying RAMs. The 8-inch length is provided by using the same structural 8-inch-long by 102-inch-diameter cylinder used in the sortie RAM and RSM. It is located between the interface structural assembly and the 45-degree cone section. The aft end of the welded assembly has a closure dome mating at the 102-inch ring in the basic configuration.

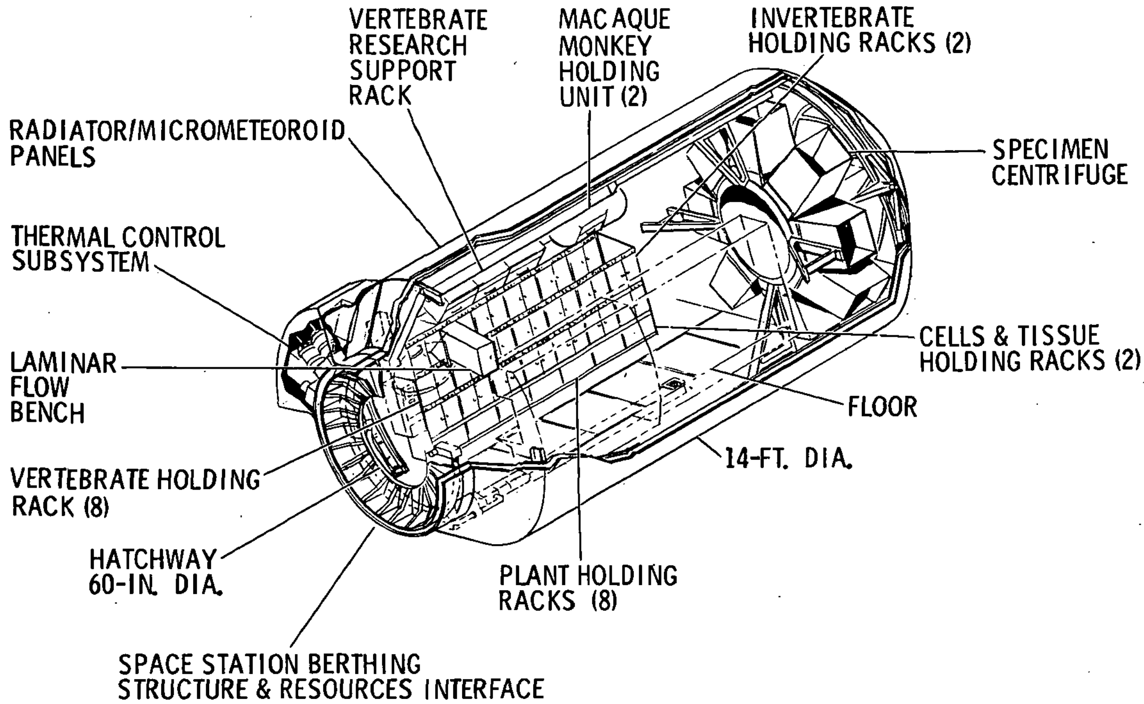


Figure 3-46. Station-Attached RAM Payload Module

The external surface of the pressure shell is totally covered with meteoroid bumper panels. Those panels over the main constant section also contain integral fluid lines that serve as the heat rejection radiator. About 390 square feet are available on 18-foot long modules and 820 square feet on 32-foot long modules.

Five orbiter attach fittings are located on each RAM payload module with the 18-foot version identical to the sortie RAM.

A special enclosure dome is added on some of the station-attached RAM payload modules to provide a shirtsleeve working environment to enclose the deployable external sensors of the Earth Observation and Communication/Navigation experiments. This dome is in addition to and over the normal cabin end closure. A 12-inch-long fixed collar bolted and sealed to the primary hull structure at the 160-inch diameter serves as the base for latching, sealing, and actuation of the deployable dome. The dome constant section, aft cone, and end closure are of the same structural components as are used in other pressurized RAM structures.

The internal floor is 46 inches below the horizontal centerline and consists of a fixed section along each wall, with removable sections 60 inches wide through the center. This is the same as used in the sortie RAM and is merely extended for the 32-foot length.

Essential air conditioning components are installed below the floor with ducting routed forward, around the interface assembly, and up and across the module along the +Z surface. The installation is the same as for the sortie RAM but provisions for LiOH canisters are omitted.

An electrical distribution center is located forward in the left side (-Y) in the conical transition area above the IVA control station. This center contains power, control, and data circuits.

Station-attached RAM payload modules provide their own heat rejection and control system. The components are the same as used on the sortie RAM, and are located internally and externally the same as on the sortie RAM. However, the RAM payload modules use an environment protection cover for the external components.

Cabinets for two IVA suits and three umbilical cords are located on each side of the vehicle in the forward transition cone area. Just above each are the IVA control stations with face masks. The umbilicals plug in at these stations. The left IVA control station and right suit/umbilical storage is similar to the sortie RAM installation.

A cabinet enclosure for houskeeping equipment is located on the forward right-hand side in the conical transition area above the IVA control station. Virtually all of the internal volume above the floor is available for experiment apparatus installation.

3.1.3.2 Structure. The structure of the RAM payload module, Figure 3-47, consists of a 160-inch-diameter cylinder 288 inches (or 120 inches) long sandwiched between two 45-degree conical bulkheads. A spherical closure bulkhead is bolted to the aft conical bulkhead. The docking adapter is bolted to either the 8-inch adapter section

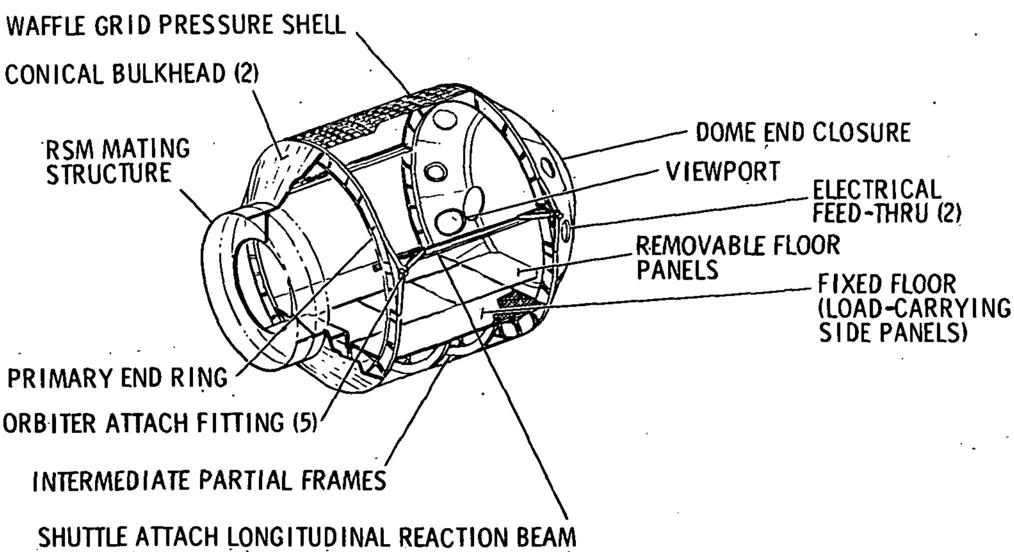


Figure 3-47. Typical RAM Payload Module Structure

on the station-attached RAM payload module or directly to the conical bulkhead on the sortie RAM payload module. Both modules have a floor structure that extends over the forward 120 inches of the cylindrical section and which is identical to the sortie RAM floor. The utility tunnels are also identical to those used on sortie RAMs.

Docking Adapter

The docking adapter carried throughout this study is the design developed for the modular space station and identified by the MDAC drawing 1B80190. It is an integrally machined adapter section made from a 2219-T852 Al-alloy ring forging 102 inches in diameter and 15 inches long. It houses the androgynous docking system, which used a square docking frame. The docking frame is manipulated with eight hydraulic/air attenuator actuators and has a latching system with provision for 12 active latches on each side of the interface. It incorporates a 98-inch-diameter inflatable seal at the interface and also has a nominally 60-inch-diameter hatch on the centerline. The docking adapter can be attached to the conical bulkhead or the 102-inch-diameter adapter using a bolting flange and static seal.

102-Inch-Diameter Adapter

This adapter is made from a one-piece roll-ring forging of 2219-T852 aluminum alloy as an integrally machined thick-wall cylinder with end-bolt circle flanges.

Cylindrical Sidewall

The cylindrical sidewall used on this module consists of three panels 288 inches long rolled to the 160-inch diameter. It has two primary end frames identical to those used on the sortie RAM. Two longitudinal I beams are welded into the cylindrical section 15 degrees above the horizontal centerline. These two beams are identical to those on the sortie RAM except for their lengths. The cylindrical panels are made with integrally machined waffle-grid stiffeners. The type of waffle selected is a 5-inch 20-degree square grid with the stiffeners on the outside of the module. The depth of the grid is 1 inch, the stiffeners are 0.050 inch thick, and the skin thickness is 0.070 inch. The cylindrical panels, the primary rings, and the horizontal beams are made from 2219 aluminum alloy.

The Conical Bulkhead

The 45-degree conical bulkhead provides the transition between the 160-inch-diameter cylindrical sidewall and the docking adapter. The bulkheads are made from three segments welded together at a longitudinal seam. Each segment consists of a 0.055-inch skin with longitudinal and integrally machined blade stiffeners 1 inch high and 0.10 inch wide.

Each segment also has a frame integrally machined for the windows, although windows are installed in the aft bulkhead only. The attachment to the cylinder is a welded joint

at the end frame. The 102-inch-diameter interface is a bolt ring welded to the cone. These bulkheads are also made from 2219 aluminum alloy.

Closure Bulkhead

This bulkhead forms a simple membrane closure for the aft end of the RAM payload module. The membrane is a portion of a sphere and is welded to a ring bolted to the 102-inch-diameter interface of the aft conical bulkhead. The membrane is 0.055 inch thick 2219-T851 aluminum alloy; the ring is 2219-T852 alloy.

Secondary Structure

The secondary structure comprises the floors, the utility tunnels and ceiling components, and the external equipment support structure. The floors are horizontal (i.e., parallel to the X-Y axis) and are made from two fixed sections running along each wall with five removable 60-inch-wide panels through the center. The fixed sections are 3-inch-deep aluminum honeycomb, and the removable panels are 1-inch-deep aluminum honeycomb.

The 3-inch-deep side panels are 31 inches wide by 124 inches long, extending between the outer edge of the circumferential ring caps. The edges of the panels are finished by bonding 3-inch-deep channel and zee sections between the face sheets. The zee sections are toward the center and pressure wall (Y plane) and the channel sections are at the ends. The zee at the outer edge is supported by a drag angle secured to the pressure wall and to the circumferential rings on each end.

Support along the inboard edge of the panels consists of four vertical tubular struts extending to the circumferential rings and two intermediate partial frames. The partial frames are J-sections attached to the pressure wall and run circumferentially under the floor between the floor intersections with the pressure shell.

Spanning the 60 inches between the side floor panels are four intercostals equally spaced (40 inches on center) between the centers of the circumferential frames. The intercostals are hat sections, the flanges of which are secured to the protruding leg of the side panels.

The center section panels are of aluminum honeycomb sandwich construction. The edges are closed out by either a 1-inch-deep channel or a zee section. Zee sections are along the forward and aft edges (the legs securing to the intercostals), and the channel sections are adjacent to the side panels. These panels are removable and are supported by the intercostals only. The aft panel attaches along its forward edge to the aft intercostal and is clipped at two places to the 102-inch-diameter aft structural ring.

The forward removable panel extends from the forward intercostal to the hatch bulkhead. This panel is 6 inches above the remainder of the floor to clear the EC/LS ducting. The forward right cover is also cut out around the semi-circular duct. Additional side edge members reinforce this panel. Attachment is to the forward intercostal and the hatch bulkhead.

A common set of secondary structural components comprises the ceiling structure inside the module. The RAM payload module has two utility tunnels 44 inches from the Z centerline and 36 inches from the X centerline plus a single tunnel on the Z centerline that is 24 inches wide and 70 inches from the X centerline.

Environment Protection

The radiator/meteoroid bumper for the 18-foot RAM payload module is identical to that of the sortie RAM, which is made from a sandwich of 0.016-inch outer and 0.010-inch inner aluminum skins bonded to a high-temperature polyurethane foam core. The radiator/bumper panels cover the cylindrical portion of the module and are split into sets of eight 45-degree sections. Each panel contains 15 fluid passages installed longitudinally; four of these are integral with an I-shaped extruded stiffener and the others in a D-shaped extrusion bonded within the sandwich. The fluid passages are connected at the ends of the panels in a radial direction. These connections are made through a valving system that controls the fluid flow in the eight panels. The panels are about 5.4 by 9 feet and are attached to the sidewall at both ends through hinge fittings that allow the panel to expand or contract under temperature variations.

For the 32-foot RAM payload module, the environmental protection over the cylindrical section is made from two sets of identical radiator/meteoroid bumper panels 8 feet long and a set 3 feet long.

Environmental protection of the conical bulkhead and the closure dome uses the same sandwich construction as the cylindrical section, but without the radiator tubes.

Access covers are made in eight sections and are attached to the cylindrical section at the end frames with slip joints. These covers may be removed to expose the radiator manifold and the hoist fitting attachements. Other access panels on the cylindrical section are removed to expose the ground handling and transportation fittings.

The entire surface area of the module with the exception of the docking interface is covered with 45 layers of SuperFloc insulation. The insulation is supported on fiberglass clips and attached to the bulkheads and the cylindrical sidewall by non-metallic fasteners.

RAM Payload Module/Orbiter Attachment Fittings

The attachment fitting concept selected for RAM payload modules is a five-point reaction statically determinate system. The five fittings on the orbiter were assumed to

be of ball or trunion mount form located 93 inches from the Y-Z centerline and 25 inches above the Y-Y axis. The fittings on the RAM payload module are three tripod types (only one of which reacts the longitudinal load) and two simple A-frames that only react lateral loads.

The RAM payload module for sortie missions is never used in the orbiter without an RSM or sortie RAM, so it does not require the forward attachment fittings. The station-attached payload module, on the other hand, requires the full complement of five attachment fittings. It requires the fittings to be bolted to the forward primary rings.

The design for the station-attached RAM payload module uses two tripod fittings at the forward +Y and -Y and one at the rear -Y location. Two A-frame fittings are located at the forward and aft -Z positions. A beam is used to accept the local moment induced by the longitudinal load and to react this load at the two end rings. The outer flange of this I-shaped beam is welded into the cylindrical side wall, forming a splice joint for the machined panels. The beam is 12 inches deep at the load application location and tapers to 8 inches deep at the forward end and 4 inches at the aft end. An integral blade is machined on the surface of the outer flange of the beam and is used to attach the machined link that forms the third leg of the tripod fitting. Each of the tripod fittings is made from a machined steel A-frame and a machined link as the third leg. This link is attached to the A-frame through a simple clevis and to the upstanding blade of the beam through a knuckle or double clevis attachment. There is also a small beam placed at the +Y location. This beam gives symmetry to the cylindrical structure and provides a structural tie for the orbiter fittings, which will induce small loads in the longitudinal direction.

Crew Mobility/Stability Aids

Crew mobility/stability aids are required to assist the crewmen in performing operations and maintenance tasks on subsystems and experiments. These tasks include such things as hatch operation, experiment setup, reconfiguration of the RAM payload module for various mission phases, wall and equipment access, and crew coordinated activities. These crew aids can be fixed or portable and will include hand rails, foot restraints, and tether attach brackets. The specific location of these aids will be determined after a detailed crew task analysis to indicate heavy traffic or task loading areas. Representative hand hold, hand rail and leg rail mobility and stability aids are shown in Figure 3-11.

The general arrangement and orientation of RAM payload module interior equipment indicate that heavy traffic or task loading occurs at the various work stations. The primary restraint is an open metal triangular grid network in the 1-g floor position, providing capability for a compatible shoe restraint attachment of discreet locations throughout the floor area. The Astrogrid floor and the companion Astrogrid shoe

restraint are shown in Figure 3-12. The grid floor is located in the center 60 inches of the module. This floor will replace sections of the 1-inch honeycomb panel.

Hand holds and rails may be attached to equipment mounting structure or directly to the cylindrical sidewalls or bulkheads. The forces imposed by crewmen using these restraints are in the low hundreds of pounds and pose no significant structural problems. The locations of these restraints are not critical to the structure; the waffle-stiffened sidewall and the longitudinally stiffened conical bulkhead can accept these low loads at any location.

3.1.3.3 Environmental Control/Life Support (EC/LS) Subsystem. The EC/LS subsystem provides the functions shown in Figure 3-48 for up to six payload crewmen.

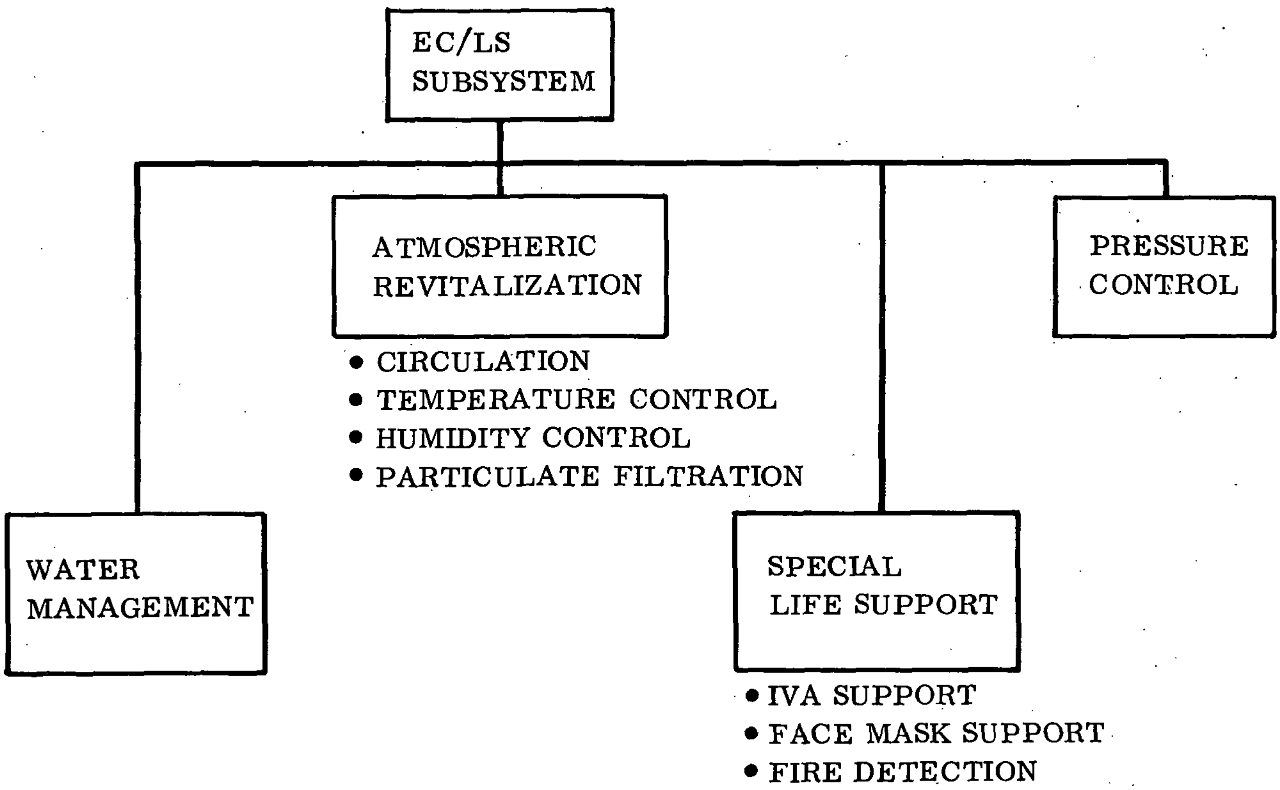


Figure 3-48. Major EC/LS Subsystem Assemblies

Since the RAM payload module operates attached to either the RSM or sortie RAM or the space station and draws support from these attached bodies, the EC/LS subsystem contains only components necessary for atmosphere circulation, temperature and humidity control, pressure control, and special life support equipment (Figure 3-49). Other normal EC/LS functions for atmospheric storage, water management, and contaminant and carbon dioxide control are supplied by either the RSM or sortie RAM or the space station. Physical characteristics of the RAM payload module EC/LS subsystem are listed in Table 3-12.

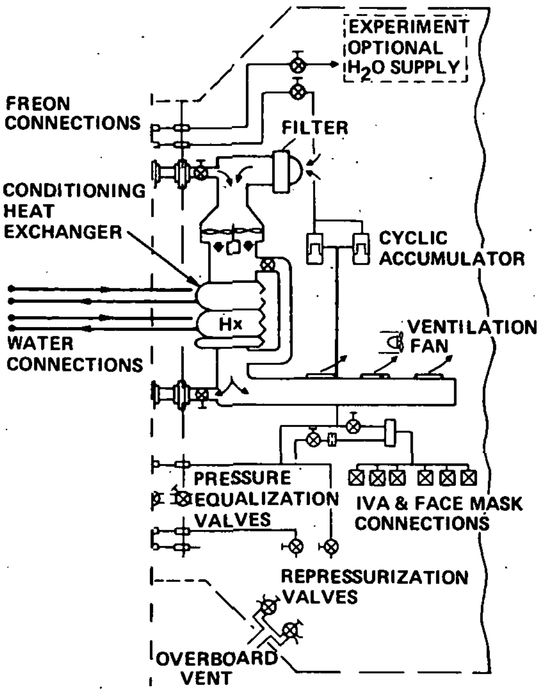


Figure 3-49. RAM Payload Module EC/LS Subsystem Functions

Atmosphere Circulation Assembly

The atmosphere circulation assembly circulates cabin atmosphere through the filter and the condensing heat exchanger to maintain atmosphere humidity and temperature within specified limits. The atmosphere composition is maintained by the space station or RSM or sortie RAM.

A filter and debris trap is provided to remove particulate matter in the atmosphere and is replaced when the pressure drop indicates a loaded filter. Downstream of the filter, two fans in parallel, each with check valves, circulate the atmosphere through the assembly. Only one fan operates at a time. A condensing heat exchanger provides humidity control. The condensate is collected in cyclic accumulators that pump the condensate to the waste water storage tanks in the space station or RSM or sortie RAM.

The cabin atmosphere flows through the return duct network, which distributes the air to provide ventilation. To meet the 20- to 50-fpm ventilation requirements, two portable ventilation fans are provided at selected locations within the module.

The air passing through the condensing heat exchanger is controlled by a by-pass to maintain the cabin temperature at a selected value between 65° F and 85° F.

Pressure Control

Minimum pressure control equipment is required for the RAM payload module. Nitrogen pressure is required to operate the humidity condensate cyclic accumulators, and module pressure relief is provided when the pressure exceeds 16 psia or negative differential pressure within the module exceeds 0.5 psi.

Special Life Support Assembly

The special life support assembly is composed of two subassemblies that provide the emergency functions of fire detection and IVA support.

Fire detection is accomplished by a condensate nuclei counter in each module located in the heat exchanger duct system. Since all materials emit large amounts of particles

Table 3-12. RAM Payload Module EC/LS Subsystem Physical Characteristics

Function	Sortie RAM Payload Module			Station-Attached RAM Payload Module		
	Weight (lb)	Volume (cu ft)	Power (Watts)	Weight (lb)	Volume (cu ft)	Power (Watts)
Atmosphere Revitalization	177	11.0	270	177	11.0	270
Pressure Control	17.5	0.1		13	0.1	
Water Management	12	0.1		12	0.1	
Special Life Support	12	0.2	10	6	0.2	10
Totals	218.5	11.4	280	208	11.4	280

when materials are approaching ignition temperatures, incipient fire hazards are detected by an increased particle count.

Connections for six IVA umbilicals are required. Support is limited to a purge flow of oxygen to IVA suits in the event of contingency depressurized or contaminated cabin operations. Oxygen flow is activated manually.

3.1.3.4 Electrical Power Subsystem. The electrical power subsystem (EPS) provides conversion, conditioning, distribution, and control for subsystems and integrated experiment payloads.

Power Generation

There is no primary power generation within the payload module. Power is supplied by either the RSM or sortie RAM or the space station. For the station-attached RAM payload modules, the prime power must be conditioned to provide the 28 vdc required by the RAM distribution system. This requires dc/dc converters for an interface with the MDAC station or ac/dc conversion for an interface with the NR station (Figure 3-50).

Distribution, Conditioning and Control

The distribution concept employs spacecraft-proven technology of 28 vdc and 115/200 vac, 400 Hz distribution. Circuit protection and switching design are based on space shuttle technology and use solid-state power controllers for loads up to ten amps. Larger loads use hybrid power controllers with solid-state elements for control and protection and electromechanical elements for power switching. A generally centralized power conditioning concept is used because it was demonstrated to be more cost effective and to require less weight and volume.

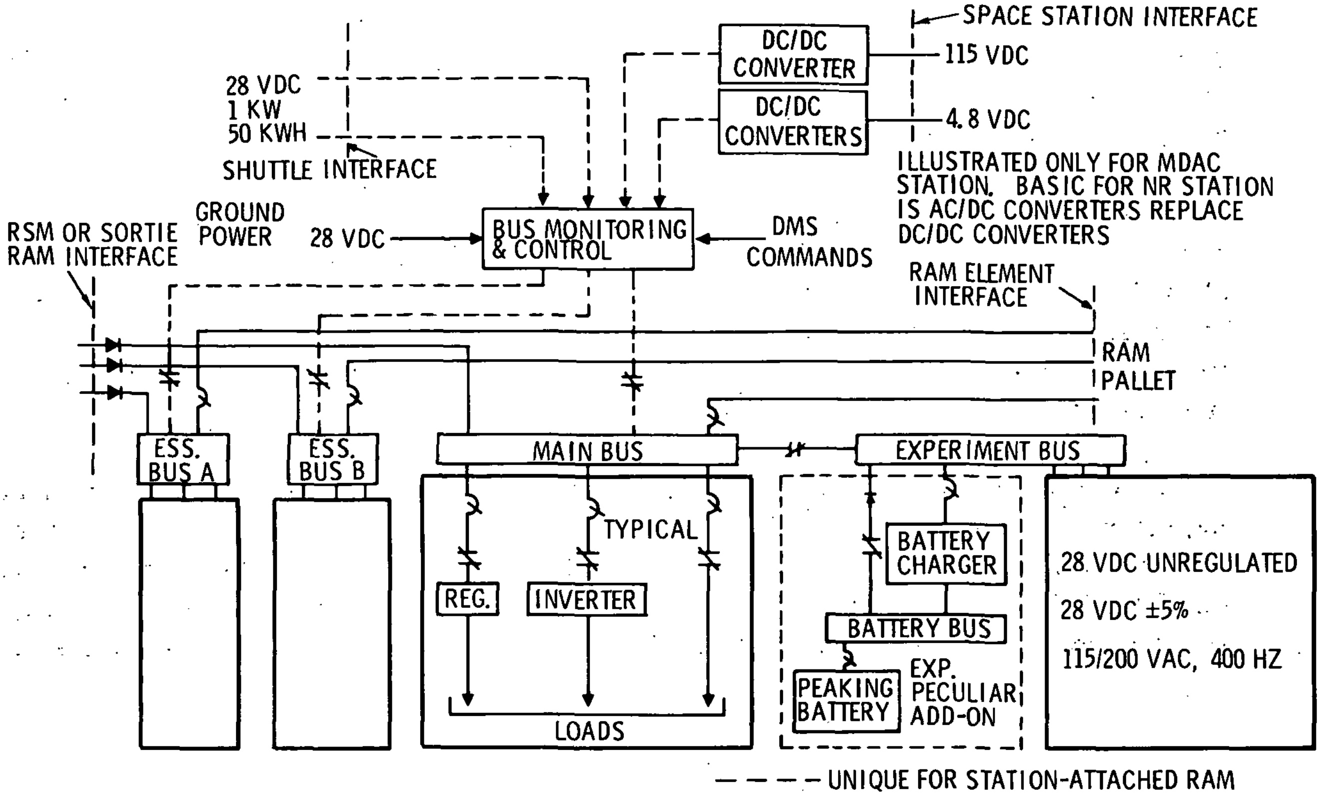


Figure 3-50. RAM Payload Module EPS Schematic

The EPS provides three independent power channels (Figure 3-50): a main bus and two essential (emergency) buses plus controlability. The main bus powers all normal operations including an experiment bus, and the essential buses satisfy the requirement to sustain two failures. The electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contactors for the station-attached mode. Provisions are included to interface with an attached RAM pallet while maintaining the capability to sustain two failures for all elements.

Lighting

General area illumination for the RAM payload module is provided with fluorescent lights. Spot or high-intensity lighting will be incandescent lights. Emergency lighting uses independent circuits with independent fixtures in each compartment.

In work areas, the general area lighting is arranged so that lights may be dimmed to conserve energy when activity is reduced for extended periods. A further consideration is changing requirements in work or experiment areas; when work is shifted from one area to another, lights are dimmed in the first area and turned up to full brilliance in the second. Utility outlets are provided for portable lights and other tools.

Auxiliary Power Generation

The RAM payload module used for sortie missions includes auxiliary power in the form of 500 amp-hr silver-zinc battery kits identical to those used for sortie RAM. These batteries provide peaking power for loads over 7 kW.

The RAM payload module for station-attached missions requires peaking batteries for some payloads. This peaking power is provided by nickel-cadmium batteries because of the long mission duration and cycle life required. For commonality, 36 amp-hr batteries of Skylab design are used. (These are also in common usage on the free-flying RAM.) The requirement for auxiliary power during ascent, a one-time operation, is satisfied by silver-zinc batteries.

3.1.3.5 Habitability Subsystem. Habitability functions provide for crew needs including personal equipment, general equipment, furnishings, hygiene and waste, emergency and survival equipment, and food management. Implementation of these requirements for the RAM payload module attached to a space station is presented in Figure 3-51, which shows that the space station provides all living provisions. For sortie mission

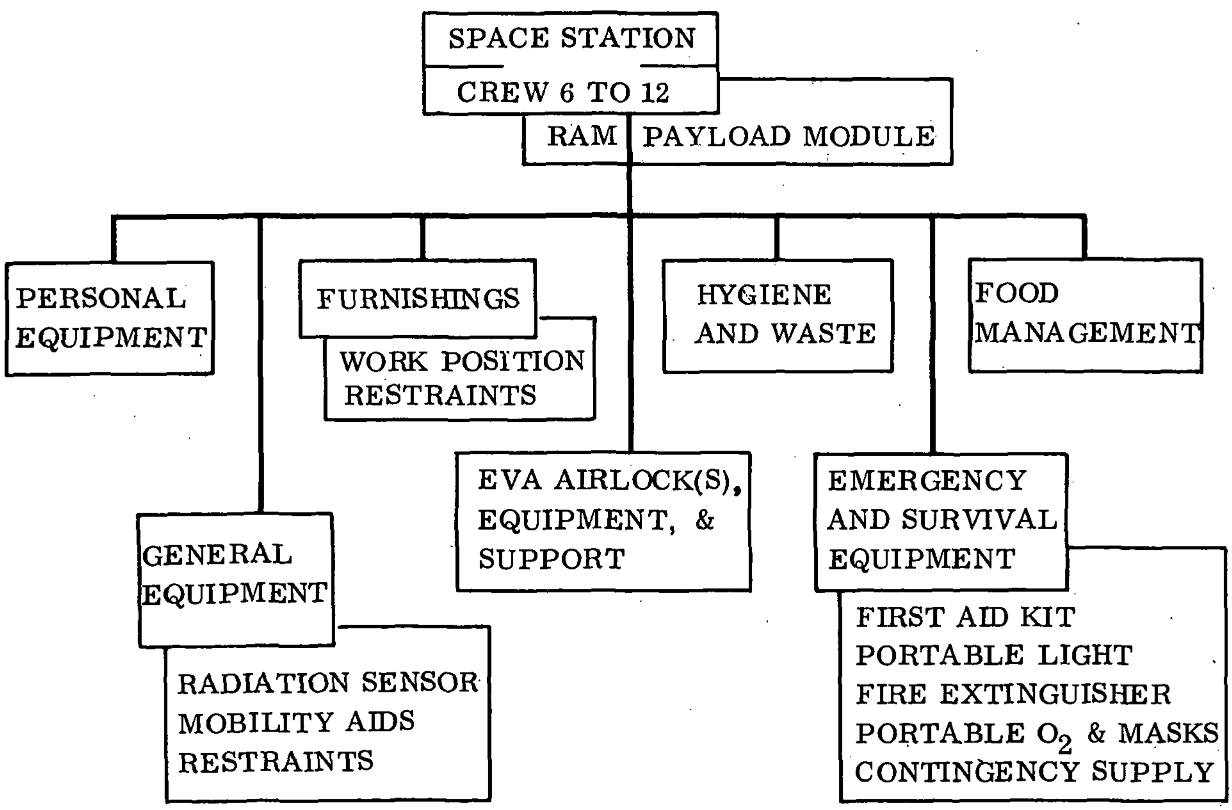


Figure 3-51. Station-Attached RAM Payload Module Habitability Provisions

RAM payload modules, the RSM provides all living provisions as shown in Figure 3-35. The only difference between the two operational modes is in EVA/IVA equipment and storage provisions. It has been assumed that space-station crew personnel will provide their own suits, umbilicals, and maintenance kits, if necessary, when they are on duty in RAM payload modules. Since the space station or RSM provides the necessary habitability provisions for crew needs, the RAM payload modules provide those habitability provisions necessary for performing experiment operations. These include emergency equipment, mobility and restraint devices, and miscellaneous items such as cleaning equipment, data and tools.

3.1.3.6 Communications Subsystem. No communications are required for the RAM payload module. The shuttle/RSM or sortie RAM or space station provides the required communication support.

3.1.3.7 Data Management and Onboard Checkout Subsystems. The data management subsystem in the RAM payload module records analog video (typically TV) on magnetic tape at rates between 2 and 5 MHz. Interface with the RSM is by the multiplex system for low-rate data and via hardwire for experiment wideband data. Data management subsystem equipment carried in the payload module include data interface units (DIUs), a magnetic tape recorder, an analog multiplexer and switch or recorder control, up to 10 reels of analog magnetic tape, and additional reels of digital magnetic tape to support the digital magnetic recorder carried in the RSM.

The station-attached RAM payload module data-handling concept is to transfer all experiment data to the space station for processing, storage, and/or transmission. The maximum data volume in 3.4×10^{11} bits/orbit at a maximum rate of 51.4 Mbps. As shown in Figure 3-52, a full multiplex data and command distribution system is used for control and monitoring of all subsystems and experiment equipment (1000 signals typical). The fully multiplex system interfaces with the space-station data but via a remote acquisition control unit (RACU) for transfer of low-rate data. High-rate data is hardwired to the space station. A single small 12k memory computer is included in the data management subsystem. Allocation of the computer for RAM payload modules was dictated by the boost-to-dock management requirements for subsystems.

The onboard checkout subsystem (OCS) for the RAM payload module for a sortie mission performs checkout, status monitoring, fault isolation, redundancy switching, and C&W monitoring of the payload experimental equipment and the RAM payload module subsystems. Onboard checkout is performed from within the supporting RSM or sortie RAM using the CDMS data processor, data distribution system, and interfacing units. The RSM or sortie RAM supplies a stimuli generator to activate subsystems for checkout and fault isolation. It also provides a caution and warning (C&W) logic module that monitors caution and warning conditions aboard the RAM payload module. This function is performed concurrently with, but independent of, other

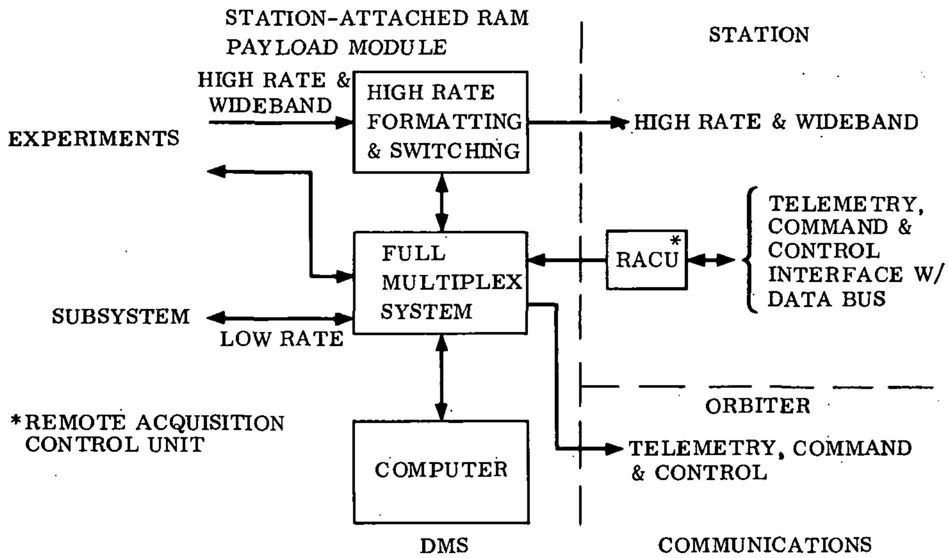


Figure 3-52. Station-Attached RAM Payload Module Control and Data Management Subsystems

checkout functions by the OCS. C&W signals are generated by the logic module and distributed by hardwire to the display and sounding alarms located in all habitable locations aboard the RSM or sortie RAM and to the orbiter. Signals are also generated and transmitted by hardwire to the computer for automatic response to the detected condition.

OCS is used during prelaunch checkout to control and monitor the activated RAM payload module subsystems and equipment during launch-readiness and boost-and-ascent phases.

The OCS for the station-attached RAM payload module (Figure 3-53) differs from the sortie RAM version in three primary areas: 1) all OCS equipment except the C&D console are located in the RAM payload module instead of the RSM, 2) checkout and fault isolation functions are initiated and controlled by the crew from the C&D console located in the space station, and 3) C&W signals detected and generated are interfaced by hardwire to the space station C&W panel for crew command action.

The C&W advises the crew members that there has been a malfunction that may be hazardous to the crew, the classification of hazard, and the identity of the specific hazard. The sortie-mission RAM payload module C&W system is simply an extension of the RSM or sortie RAM C&W systems. (See Sections 3.1.1.7 and 3.1.2.7.) For station-attached RAM payload modules, the C&W system is essentially identical to the sortie-mission RAM payload module except for the hardwire interface with the space station.

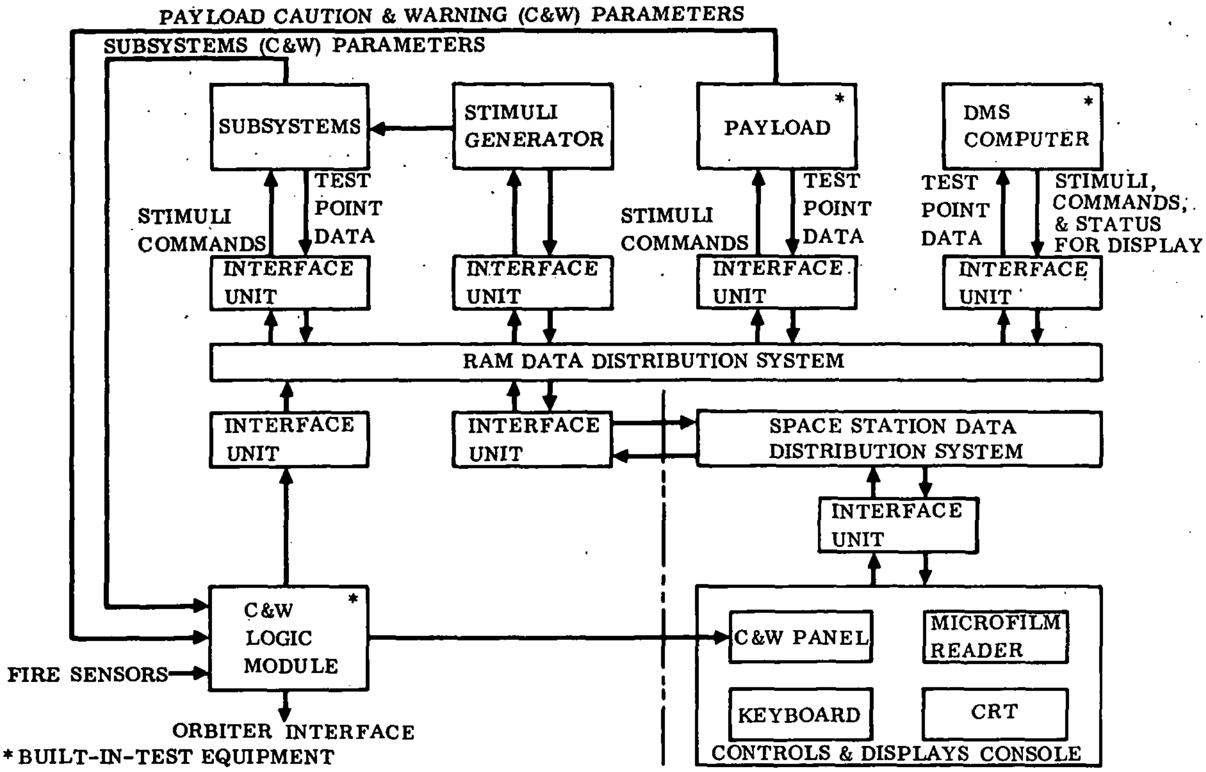


Figure 3-53. Station-Attached RAM Payload Module OCS Configuration

3.1.3.8 Control and Display (C&D) Subsystem. The only functions provided by the C&D subsystem for the RAM payload modules are 1) audio distribution and 2) caution and warning displays and alarms.

Primary C&D functions are provided by the RSM or sortie RAM for sortie missions and the space station for station-attached missions. Station-attached payload modules use portable, carry-on C&D (station provided) when physical proximity is required for experiment or subsystem management.

Audio distribution is handled by a simple extension of the RSM or sortie RAM system or interfaces with the station audio bus.

3.1.3.9 Guidance, Navigation, and Control Subsystem. There are no GN&C requirements related to either the shuttle-supported or station-attached RAM payload modules. Stabilization and control requirements exceeding the basic capabilities of the shuttle orbiter vehicle or space station will be satisfied by payload-furnished equipment.

3.1.3.10 Thermal Control Subsystem (TCS). Since thermal control is handled differently in the sortie-mode and station-attached RAM payload modules, their characteristics are discussed separately.

Sortie Mode

Thermal control of the RAM payload module for sortie operations is provided by the RSM or sortie RAM. A water coolant is provided inside the pressure shell to absorb the atmospheric and cold-plate loads, and the RAM payload module radiators are connected directly to the RSM or sortie RAM radiators. The basic heat transport system is shown schematically in Figure 3-54. Cabin air cooling requirements resulted in placing a cabin air heat exchanger in the RAM payload module. The figure shows the requirement for freon and water coolant interfaces with the RAM payload module.

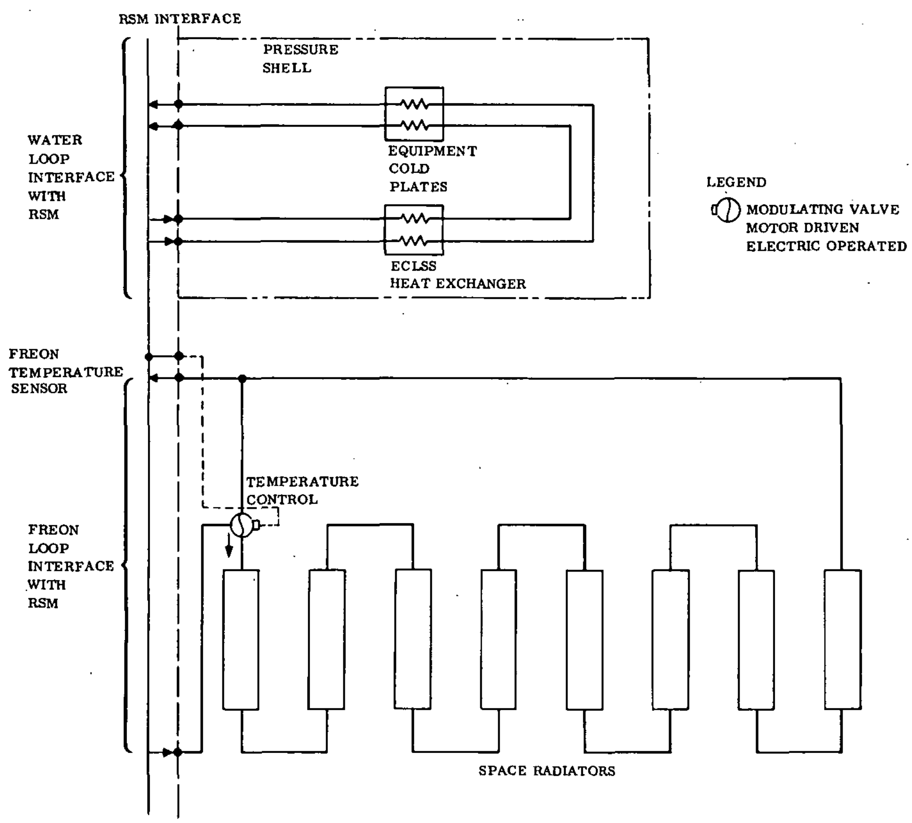


Figure 3-54. Sortie Mission RAM Payload Module TCS Schematic

Water is used as the heat transfer fluid within habitable compartments to meet the requirement of nontoxicity and nonflammability. The water loop interfaces with the freon 21 heat transport fluid through the interloop heat exchanger, which is located in the RSM or sortie RAM. The freon loop is located outside the habitable compartments and transfers heat to the space radiator for rejection to space. Freon is used because the radiator temperature can sometimes be well below the freezing point for water. A bypass valve around the radiator regulates the freon temperature to 35°F and controls variations in internal and external loads.

The TCS interfaces with the life support subsystem at the air to liquid heat exchangers. Cabin sensible and latent loads are absorbed at this point by the TCS.

There are two completely independent heat absorption systems, with each system capable of carrying the entire cooling load, thereby providing redundancy in case of component failure. Radiators do not contain redundant coolant loops, since the experiments can be powered down in the event of failures to reduce cooling requirements within the capability of basic RSM radiators.

The selected radiator configuration has 3/16-inch inner diameter longitudinal tubes spaced 8 inches apart attached to the 0.016-inch-thick outer meteoroid shield. The radiator consists of eight panels around the circumference of the vehicle, each panel containing eight parallel tubes. A 5-mil Teflon-silver coating was selected for the radiators. For sortie missions, Teflon-silver is about 10 percent better than the usual space white paint Z-93 and does not require radiator panel bypass valves to obtain its performance. The degraded coating characteristics for the Teflon-silver used in sortie performance analysis are 0.09 for absorptance and 0.80 for emissivity.

Radiator performance depends on the surface coating, RAM element/orbiter configuration, orbit, and vehicle orientation. The net radiator heat rejection for the various design conditions are shown in Figure 3-55. All payloads can reject the required cooling load and maintain the cabin temperature within the 65°F range (some payloads require water boiling to supplement the radiators).

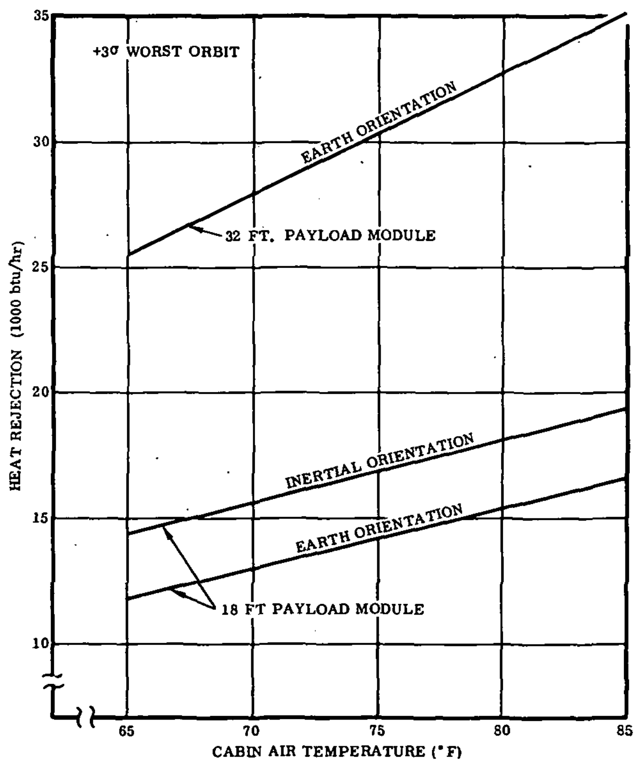


Figure 3-55. Sortie Mission RAM Payload Module Radiator Performance

Station Attached Mode

When operating in the station-attached mode, the RAM payload module must provide its own thermal control and thus requires a complete TCS. The schematic shown in Figure 3-56 is similar to that for the sortie RAM minus a fuel-cell heat exchanger and with the addition of radiator panel bypass valves.

Except for the radiator panel bypass valves the components are identical to those used in the sortie RAM. The panel bypass valves require additional freon lines to provide connection between the freon inlet and outlet.

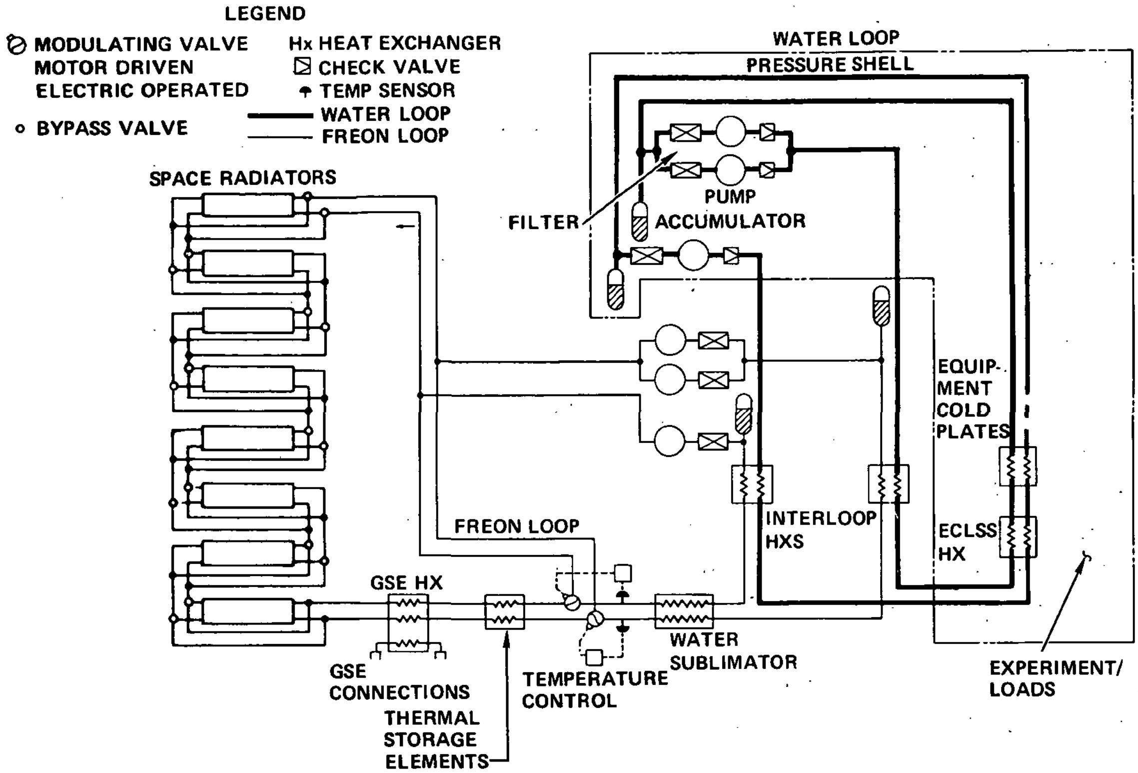


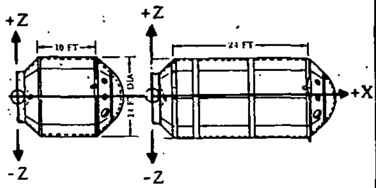
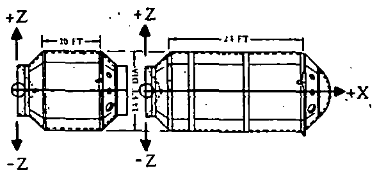
Figure 3-56. Station-Attached RAM Payload Module TCS Schematic

Since the shuttle doors are closed during launch and recovery, a water sublimator and thermal storage element (TSE) are provided. An interface heat exchanger (GSE Hx) receiving coolant from GSE is used during prelaunch and postlanding operations. There are two completely independent thermal control systems with each system capable of carrying the entire cooling load, thereby providing redundancy in case of component failure. Each fluid loop in the primary system has one active and one standby pump. The system satisfies the failure modes and effects analysis criteria.

In addition to the components described on the sortie mode operation, the station attached RAM payload module configuration has eight redundant tubes on each panel interspaced between the active tubes. The basic TCS components should be available or under development from shuttle or other space programs. Radiator unit heat rejection is less than that on the sortie-mission RAM payload modules because of the degraded coating performance. Coating degraded values are 0.24 for absorptance and 0.80 for emissivity, based on five years of exposure. Radiator panel bypass is required to prevent solar heat from being absorbed by the freon coolant system.

3.1.3.11 Mass Properties. The estimated mass properties of 18- and 32-foot long basic RAM payload modules for sortie and station-attached RAM missions are presented in Table 3-13. The estimated weights are based on the configuration designs and

Table 3-13. Basic* RAM Payload Module Mass Properties Summary

Subsystems (MIL-M-38310A)	Sortie Missions		Station Attached Missions	
				
	18 ft	32 ft	18 ft	32 ft
Structure	3423	5421	3543	5680
Induced Environmental Protection	1273	2136	1299	2154
Docking	238	238	238	238
Electrical Conversion and Distribution	129	160	484	515
On-Board Checkout	18	18	18	18
Data Management	0	0	99	99
Displays and Controls	0	0	35	35
Electrical Wiring	186	240	186	240
Atmospheric Control	232	232	227	227
Thermal Control	93	93	952	952
Life Support	24	24	20	20
Interiors	182	182	266	266
Basic Weight (lb)	5798	8744	7367	10444
Center of Gravity Location (inches from datum on sketch)				
X	99	175	96	161
Y	-1.0	-1.3	4.3	3.3
Z	-2.9	-5.4	2.9	-3.1
Mass Moment of Inertia About CG (slug-ft^2)				
I_{XX}	5809	9439	7130	10900
I_{YY}	7462	28810	8826	35240
I_{ZZ}	7264	28440	9067	35490
Product of Inertia About CG (slug-ft^2)				
I_{XY}	-88	2	-228	-1240
I_{YZ}	-50	-23	174	92
I_{XZ}	-24	67	-239	-557

*Factory complete condition. Excludes subsystem add-ons, experiments, crew and crew equipment, residuals, reserves, and in-flight losses.

subsystems data discussed in Section 3.1.3.1 through 3.1.3.10. Allowances have been included in the weights for miscellaneous hardware items not fully defined in the design. The weight breakdown format used is per MIL-M-38310A.

The basic RAM payload module weights shown in Table 3-13 represent factory-complete articles with no subsystem add-ons, experiments, crew personal gear, residuals, reserves, or expendables. These modules are designed for housing the experiments in sortie and station-attached RAM missions.

3.1.3.12 User Provisions. The provisions and capabilities in the RAM payload modules for the performance and support of experiments is presented in Table 3-14 for the sortie mission mode and in Table 3-15 for the station-attached mode. Net experiment support capability is derived from the total capability shown by subtracting resource and subsystem requirements.

Optional integration equipment as described in Section 6.4 is also available to extend the experiment support capabilities of the RAM payload module.

Table 3-14. Sortie Mission RAM Payload Module Support Capabilities

Parameter	Total Capability	Net Capability For Experiments	Explanatory Note
1. Volume (ft^3)	18-ft: 1910 32-ft: 3860	18-ft: 900 32-ft: 2000	
2. Crew size/manhours per day	4 to 6/48 to 72	4 to 6/45.5 to 69.5	Habitability for 2 provided by shuttle, remainder by RSM.
3. Electrical Power			
Total, unregulated (±15%)	7.0 kW, 3500 kW-hr	4.4 kW, 1900 kW-hr	Provided by RSM (except peaking power)
28 vdc +5%/115 vac, 400 Hz	—	1.5 kW, 1.25 kva	
4. Data Acquisition			
Max data rate	67 Mbps	67 Mbps	
Storage (b/reel/No. of reels)	$6.6 \times 10^{10}/29$	$6.2 \times 10^{10}/29$	
5. Control and Display (C&D)	Includes subsystem dedicated C&D	Payload-dedicated C&D caution and warning intercom	RSM provides C&D console
6. Communications Transmission capacity	Ground network: 1 Mbps peak Max contact = 3 to 11% of time	Ground network: 1 Mbps peak Max contact = 3 to 11% of time	Shuttle provided
7. Guidance, Navigation, & Control			Shuttle provided
Pointing accuracy (deg)/stability (deg/sec)	±0.5/±0.03	±0.5/±0.03	
Position (n. mi.)/velocity (fps)	±1/±10	±1/±10	
8. Thermal Control			Total heat rejection rate is for RAM pointed away from earth.
Air temp/heat rejection	18-ft: 30,400 Btu/hr	70 to 75° F/0 to 7500 Btu/hr	
Cold plate temp/heat rejection	32-ft: 48,000 Btu/hr	70 to 100° F/0 to 7500 Btu/hr	
9. Viewports	Three viewports 12 inches in diameter, located on the aft 45-degree conical section provide hemispherical coverage.	Three viewports 12 inches in diameter, located on the aft 45-degree conical section provide hemispherical coverage.	
10. Feedthroughs	Two 8-inch-diameter feedthrough parts located on the aft 45-degree conical section.	Two 8-inch-diameter feedthrough parts located on the aft 45-degree conical section.	

Table 3-15. Station-Attached RAM Payload Module Support Capabilities

Parameter	Total Capability	Net Capability for Experiments	Explanatory Note
1. Volume (ft^3)	18 ft: 1950 32 ft: 3900	18-ft: 900 32-ft: 2000	
2. Crew size/manhours per day	4 to 6/48 to 72	4 to 6/45.5 to 69.5	Habitability provided by station.
3. Electrical Power Total, unregulated (±15%) 28 vdc ±5%/115 vac, 400 Hz	 4.8 kW (station provided)	 3.2 kW 1.5 kW/1.25 kva	
4. Data Acquisition Max data rate Storage (b/reel/No. of reels)	 25 Mbps 1.0×10^{10}/stored in station	 25 Mbps 1.0×10^{10}/stored in station	 Station provided
5. Control and Display	Includes subsystem dedicated C&D	Payload dedicated C&D console Caution and warning intercom	Station provides C&D
6. Communications Transmission capacity	TDRS: 10 Mbps Ground network: 1 Mbps	Station provided	Station provided
7. Guidance, Navigation, & Control Pointing accuracy (deg)/ stability (deg/sec) Position (n. mi.)/velocity (fps)	 ±0.25/±0.05 ±1/TBD from station	 ±0.25/±0.05 ±1/TBD from station	 Station provided
8. Thermal Control Air temp/heat rejection Cold plate temp/heat rejection	 18-ft: 11,300 Btu/hr 32-ft: 24,400 Btu/hr	 85 to 105° F/0 to 6600 Btu/hr 85 to 100° F/0 to 6600 Btu/hr	Total heat rejection rate is for module pointed away from earth.
9. Viewports	Three viewports, 12 inches in diameter, located on the aft 45-degree conical section provide hemispherical coverage.	Three viewports, 12 inches in diameter, located on the aft 45-degree conical section provide hemispherical coverage	
10. Feedthroughs	Two 8-inch-diameter feedthrough ports located on the aft 45-degree conical section.	Two 8-inch-diameter feedthrough ports located on the aft 45-degree conical section.	

3.2 UNPRESSURIZED RAM (PALLET)

Some of the experiment payloads for the seven-day sortie missions require large mounting surfaces but do not need to be located in the pressurized RAM. The requirement for large payloads external to the pressurized RAM is derived from the sortie Astronomy experiment payloads and the Technology experiments involving propellant transfer and the maneuvering work platform experiment. The RAM pallet is used only on sortie missions and is always used in conjunction with either the sortie RAM or the RAM payload module.

3.2.1 <u>CONFIGURATION.</u> The RAM pallet shown in Figure 3-57 is used by attaching it to either a sortie RAM or an 18-foot RAM payload module. The design is driven by structural rigidity requirements, payload size, and viewing and exposure requirements. It also provides utility services distribution to the external experiment payload. Characteristics of the RAM pallet are presented in Table 3-16.

The Astronomy payloads have pointing requirements necessitating the use of large gimbal mounts and large CMGs. These add-on items are classified as payload integration equipment.

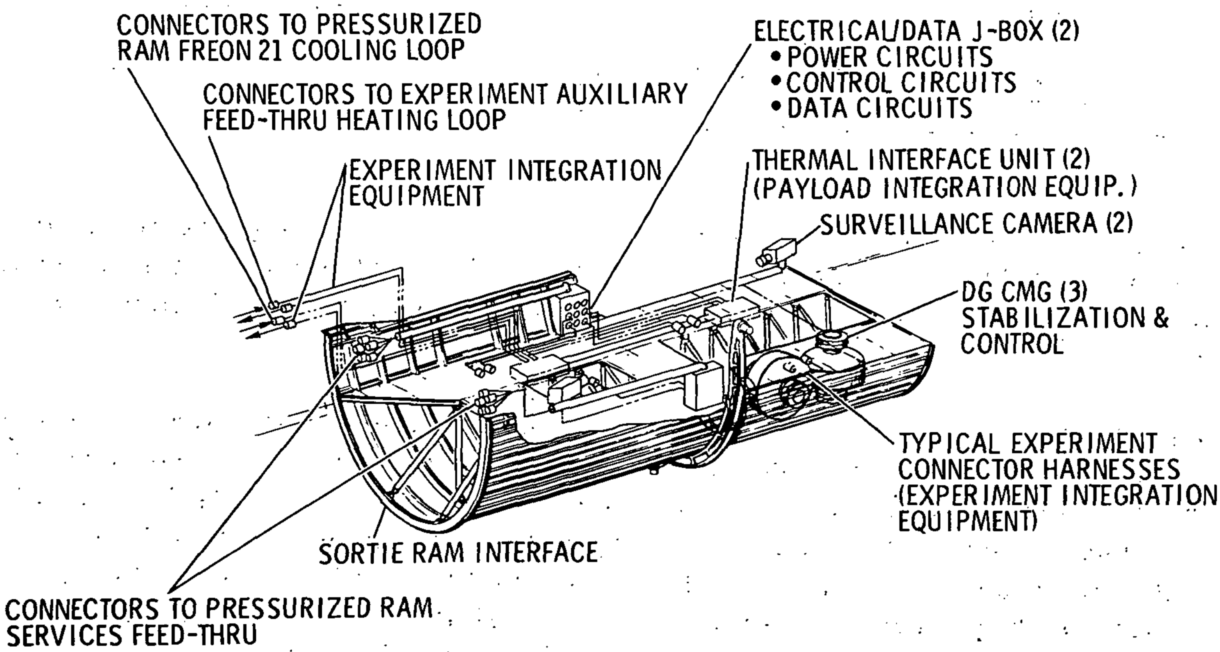


Figure 3-57. RAM Pallet General Arrangement

Table 3-16. RAM Pallet Characteristics

Parameter	Basic Configuration
Overall Length	312.0 in. (26.0 ft)
Nominal Width	162.0 in. (13.5 ft)
Max. Width (across orbiter attach frame)	168.0 in. (14.0 ft)
Max. Height (excluding orbiter attach fittings)	93.0 in. (7.75 ft)
Floor - Nominal Side; Gross Area	12.3 ft × 21.7 ft; 280 ft^2
Support Fittings, Orbiter Attach	2
Type of Construction	Sheet/Stringer Half Shell
Material	Aluminum Alloy
Electrical Power	
Distribution Voltage from Supporting Module	28 vdc
Conversion Equipment	Experiment Dependent
Electrical Wiring	Distribution on Palletized RAM
Communications	
Control and Monitor	Hard Line to Supporting Module
TV Cameras (Standard Provision)	2
Thermal Control	
Standard Provisions	Fluid Lines Plumbed to Supporting Module
Thermal Capacity	1250/Btu/hr Maximum
Data Management	
Standard Provisions	Digital Interface Unit. Hard Line to supporting module.
Stabilization and Attitude Control	
Double Gimbal CMGs (2300 ft-lb-sec)	Provisions for 3
Gimbals	Provisions for 2 at 162 inches on center
Weight, Dry (Without experiment integration equipment)	2204 lb

The forward end (-X) of the RAM pallet interfaces directly to the pressurized module primary structure at the 160-inch diameter. The RAM pallet structure is a shell of sheet/stringer construction and uses aluminum alloys with riveted and bonded joints.

Feedthroughs on the pressurized module aft conical section on each side of the vertical centerline provide umbilical connect for direct cabling power, commands, and data to the experiment apparatus. Electrical power is provided by the sortie RAM or RSM. Communication and data management support are provided by the sortie RAM or the RSM. Equipment on the RAM pallet is limited to data terminal components. Thermal control for the payload will also be supplied by the sortie RAM or RSM. The only equipment on the RAM pallet will be freon fluid lines and cold plates to maintain proper payload temperature(s).

Payloads require a pointing accuracy (±1.0 arc-sec) and stability (±0.5 arc-sec/observation) considerably in excess of the capability of the shuttle orbiter; the precise

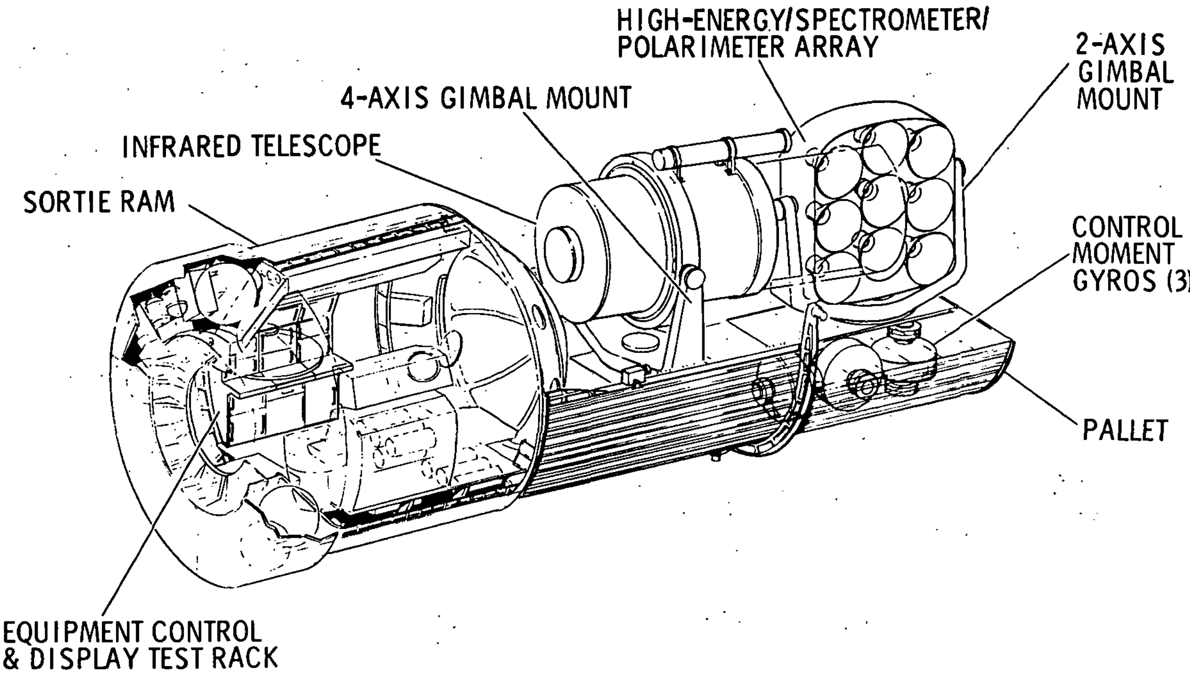


Figure 3-58. Astronomy Sortie Mission Payload

pointing and stability requirements are satisfied by narrow range, fine point, two-axis gimbaling. For payloads requiring long observation times (several hours), additional wide-angle gimbaling is required to eliminate constraints on shuttle orientation. The combination results in a wide-angle gimbal system with a fine-pointing capability. Figure 3-58 depicts the mounting of gimbals and CMGs on experiment mounting plates that bolt to the floor of the RAM pallet. This capability plus the mounting flexibility provided by the sheet/stringer construction enables the RAM pallet to accommodate payloads with wide variations in mounting requirements.

3.2.2 STRUCTURE. The RAM pallet structure, Figure 3-59, is essentially a half cylinder made from sheet metal. It is 160 inches in diameter and 310 inches long. It has a large frame 172 inches from the forward end, which is used to mount the RAM pallet/orbiter attach fittings. The forward end of the RAM pallet has a bolt ring flange that mates with a similar ring on the sortie RAM, RSM, and 18-foot RAM payload module. The RAM pallet is attached to any of these modules with high-strength bolts (Figure 3-60). The bolted joint and the forward 12 inches of the RAM pallet are covered by Super Floc insulation and a protective shield. This shield attaches to the RAM pallet structure, and at its forward end to the meteoroid bumper/radiator on the pressurized module.

A structural floor runs the length of the X-Y centerline. The side of the RAM pallet is cut down to the floor level aft of the main frame. Two major longerons are

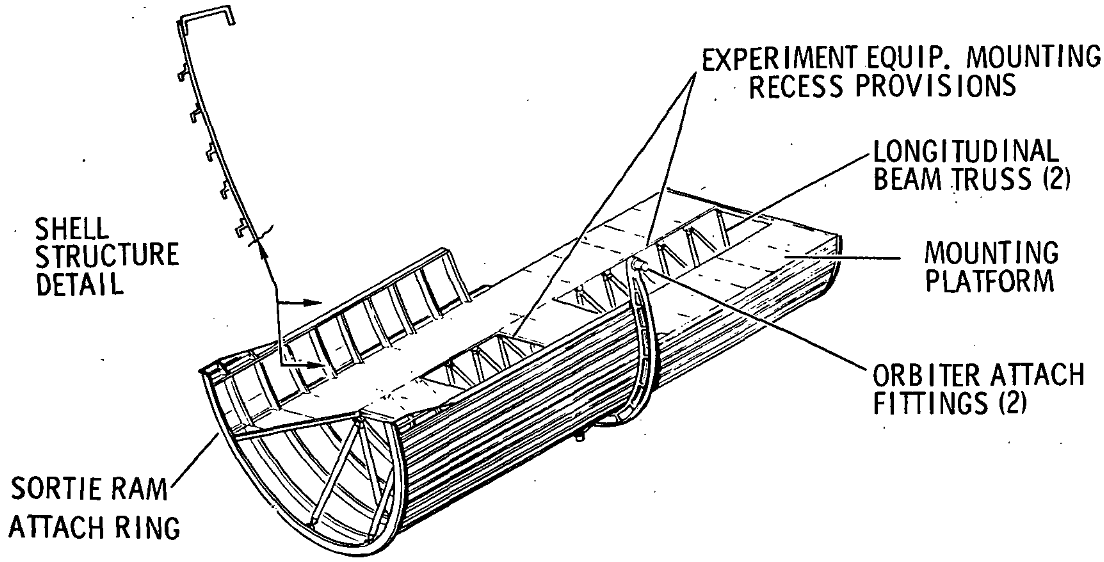


Figure 3-59. RAM Pallet Basic Structure

attached to the shell structure edge at the centerline to react the large bending loads. A machined fitting is attached to these longerons at the module or forward end. These fittings serve to spread the load into the module structure and accept local moment effects on the longeron. The floor is supported at the shell by other longerons and a pair of parallel and vertical beams. The lower caps of these beams also act as longerons.

The shell structure is a typical semi-monocoque structure with a skin that varies in thickness from 0.032 to 0.064 inch. It has a series of channel-section frames spaced every 20 inches. Attached to each frame is a channel-section beam that spans the cylindrical shell and supports the floor. The shell is stiffened with longitudinal zee-shaped stiffeners spaced 3 inches apart above the floor between the main frame and the forward ring. The remainder of the stiffeners are space 6 inches apart.

The floor of the pallet is a honeycomb structure designed to accept cutouts or to which machined plates can be attached. The machined plates are used for the telescope mounts or other equipment. In the aft end of the pallet, the floor is cut out to accept the three CMGs and their mounting frame structure.

The RAM pallet structure uses 7075 and 2024 aluminum alloys and is of riveted and bonded construction.

3.2.3 ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM. No environmental control/life support is required for the RAM pallet.

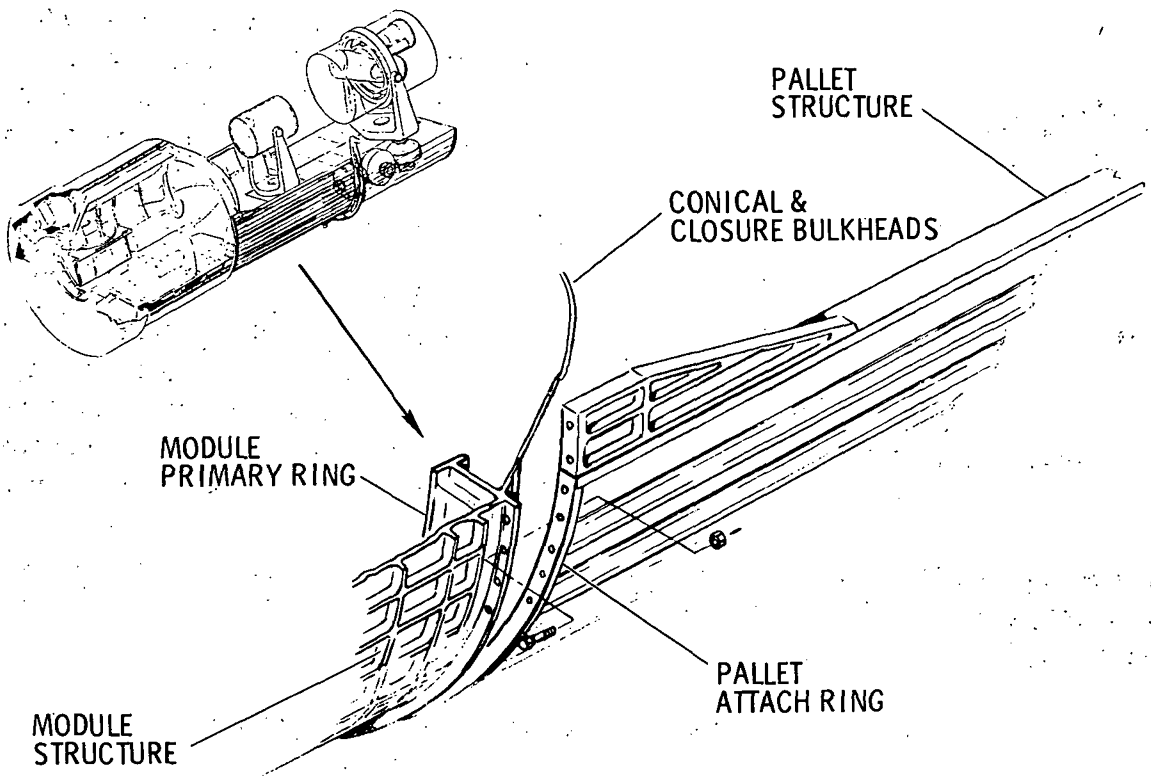


Figure 3-60. Pallet Attachment to RAM Sortie Modules

3.2.4 ELECTRICAL POWER SUBSYSTEM. The electrical power subsystem is limited to distribution of power furnished by the sortie RAM or RSM. Floodlights are provided on the RAM pallet as required for experiment operations.

3.2.5 HABITABILITY. The RAM pallet has no habitability requirements.

3.2.6 COMMUNICATIONS. No communications are required for RAM pallet.

3.2.7 DATA MANAGEMENT AND ONBOARD CHECKOUT SUBSYSTEM (OCS). The portion of the data management subsystem on the RAM pallet consists basically of five DIUs to handle low-data-rate signals that command and monitor experiment equipments and the GN&C subsystem. It also uses hardwire to transfer wideband experiment data. The full multiplex system and high-rate digital recorder located on either the sortie RAM or RSM interfaces with and supports the RAM pallet (typically, 1200 signals are involved).

3.2.8 CONTROL AND DISPLAY (C&D) SUBSYSTEM. The only C&D function required for the RAM pallet is visual monitoring of operations and inspection of equipment mounted on the RAM pallet. This function is provided by orbiter support

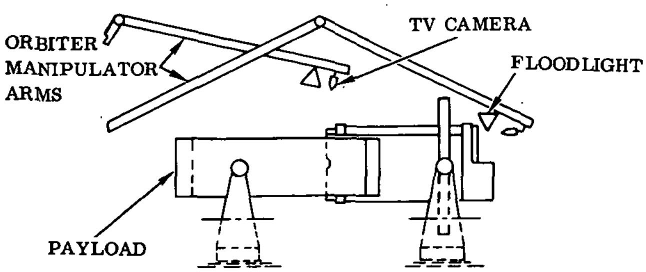


Figure 3-61. CCTV on Orbiter Manipulator

using CCTV cameras and associated floodlights located on the manipulator arms (Figure 3-61). Control of the cameras/manipulators and display of the video image is accomplished from the sortie RAM or RSM data and subsystem console.

3.2.9 GUIDANCE, NAVIGATION, & CONTROL (GN&C) SUBSYSTEM. The RAM pallet has provision for housing payload integration equipment designed to augment shuttle capabilities for the special requirements of certain payloads.

The driving GN&C requirements result from the Astronomy payload requirements for retention of orbital environment cleanliness and inertial-referenced all-altitude pointing in the fractional arc-sec range (Table 3-17).

Table 3-17. Sortie Astronomy GN&C Requirements

Requirement	Value
Pointing Augmentation	
Acquisition Accuracy	±(0.25 deg - 30 arc-sec)
Observation Accuracy	±(0.5 deg - 1 arc-sec)
Observation Stability	±(0.5 deg - 0.5 arc-sec)
Observation Time	(0 to 5) hr
Slew Rate, Acceleration	6 deg/min, 6 deg/min^2
Orbit Cleanliness	
Particulate	(10^3 to 10^4) particles/meter^3
Pressure	(10^{-6} to 10^{-7}) Torr
Magnetic	2 Gauss

The less stringent pointing requirement value could be provided by the unaugmented shuttle; more stringent requirements are provided by the payload. All-attitude pointing to acquisition accuracy is provided by the RAM pallet. Observation accuracy and stability are based on payload aspect sensing in a range at or above acquisition accuracy. Orbit cleanliness and particulate and pressure level requirements are interpreted to exclude shuttle RCS control.

Meeting the stringent acquisition and observation accuracy is accomplished by CMGs of the type and size designed for Skylab and payload gimballing assembly. CMGs are used to control the attitude of the shuttle/RAM element assembly, principally to eliminate potential shuttle RCS contamination and improve base stability (Figure 3-62).

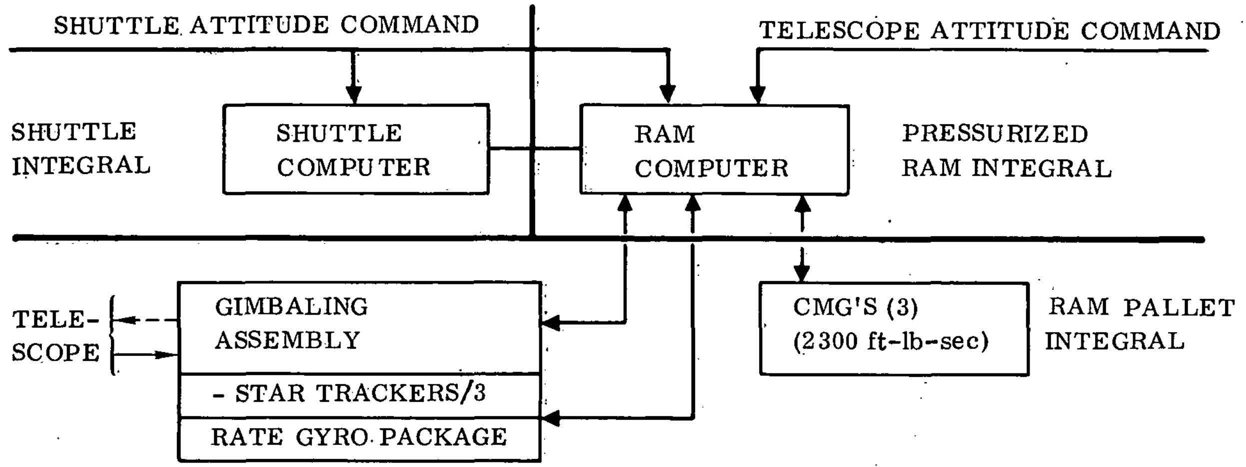


Figure 3-62. RAM Pallet Astronomy GN&C Integration Equipment Configuration

The gimbaling assembly provides three-axis wide-angle gimbaling for hemispherical telescope coverage and attitude isolation relative to the base of the RAM pallet. It also provides two axes of narrow-range experiment line-of-sight fine pointing based on error signals provided by the experiment. Fixed-head star trackers and a strap-down rate gyro package (same as those on the free-flying RAM) are mounted on the gimbaling assembly to provide all-attitude sensing to acquisition accuracy.

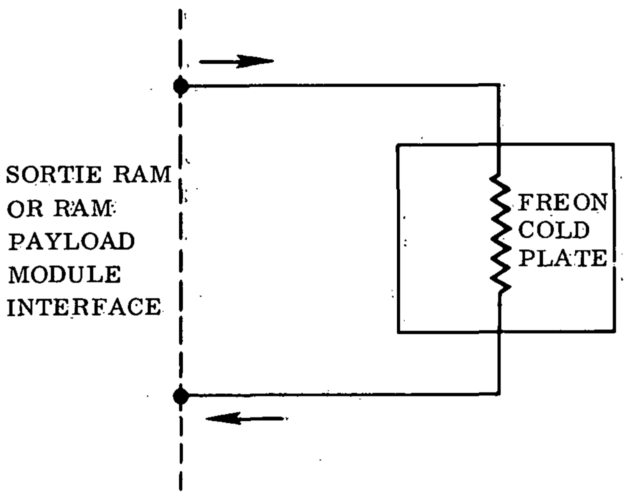
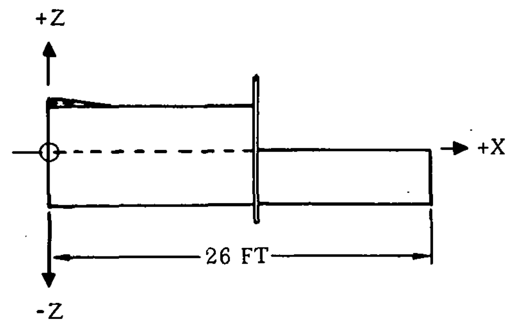


Figure 3-63. RAM Pallet TCS Schematic

3.2.10 THERMAL CONTROL SUBSYSTEM (TCS). Thermal control for the RAM pallet is provided by the sortie RAM or the RSM (when a RAM payload module is used). The freon connections to the RAM pallet are to the sortie RAM in one case and to the RAM payload module, with control provided by the RSM, in the latter case (Figure 3-63). Freon coldplates are located on the pallet to pick up the heat loads from the payload. Up to 1250 Btu/hr can be transferred from the RAM pallet to the RSM or sortie RAM TCS for ultimate rejection.

3.2.11 MASS PROPERTIES. The estimated mass properties of the basic RAM pallet are presented in Table 3-18. This RAM pallet consists of a sheet-metal structure, electrical conversion and distribution equipment and wiring, and data management digital interface units.

Table 3-18. Basic* RAM Pallet Mass Properties Summary

Subsystems (MIL-M-38310A)	
Structure	1894
Electrical Conversion and Distribution	22
Data Management	28
Electrical Wiring	260
Basic Weight (lb)	2204
Center of Gravity Location (inches from datum on sketch)	
X	153
Y	-4.4
Z	-39.9
Mass Moment of Inertia About CG (slug-ft^2)	
I_{XX}	1490
I_{YY}	3785
I_{ZZ}	4593
Product of Inertia About CG (slug-ft^2)	
I_{XY}	-46
I_{YZ}	25
I_{XZ}	-169

*Factory complete condition. Excludes subsystem add-ons, experiments, crew and crew equipment, residuals, reserves, and in-flight losses.

3.2.12 USER PROVISIONS. For experiments requiring extensive gimbals, structures, or large arrays of equipment, a RAM pallet with 2500 cubic feet of useful experiment volume may be added to a sortie RAM or to a RAM payload module and RSM combination. The addition of a RAM pallet increases the available experiment volume and does not detract from any of the other basic payload carrier support capabilities. Electrical power normally available to the pressurized modules is also available to the RAM pallet. An additional basic capability provided for payload carriers with the RAM pallet is closed-circuit TV on manipulator arms to view the RAM pallet.

Optional subsystem add-ons and experiment integration equipment as described in Section 6.4 are also available to enhance the support capability of a RAM pallet. GN&C experiment integration equipment can be used with the RAM pallet to improve pointing accuracy and stability to ±1.0 arc-sec and ±0.5 arc-sec per observation, respectively.

3.3 FREE-FLYING RAM

A prime application of the free-flying RAM is to provide a space observatory or to conduct experiments that require a low-g field for long periods of time (months). To support typical equipment, the free-flying RAM must:

a. Provide the necessary stability and fine pointing.

b. Provide for a contamination-free environment.

c. Provide for long-duration unmanned operation with only periodic revisits by the shuttle or to the space station for servicing.

d. Provide alternative orbit capability.

3.3.1 CONFIGURATION. The major difference from the other RAM elements is that the free-flying RAM operates unmanned and unpressurized for long periods in an orbit that is remote from the space station or shuttle. Periodically, the free-flying RAM will return to the space station or will rendezvous with the shuttle orbiter for pressurizing and manned on-orbit servicing. There are differences in certain subsystems depending on whether the free-flying RAM is supported by the space station or shuttle. The shuttle-supported mode is used as the baseline. In this case, a sortie RAM with an aft docking interface is deployed from the shuttle cargo bay, the shuttle performs the rendezvous and docking, and the sortie RAM provides the pressurization gases for shirt sleeve ingress into the free-flying RAM.

3.3.1.1 Baseline Shuttle-Supported Free-Flying RAM. A perspective and general arrangement of the baseline free-flying RAM are depicted in Figures 3-64 and 3-65. This payload carrier has an open-ended structure of 12-foot nominal outside diameter

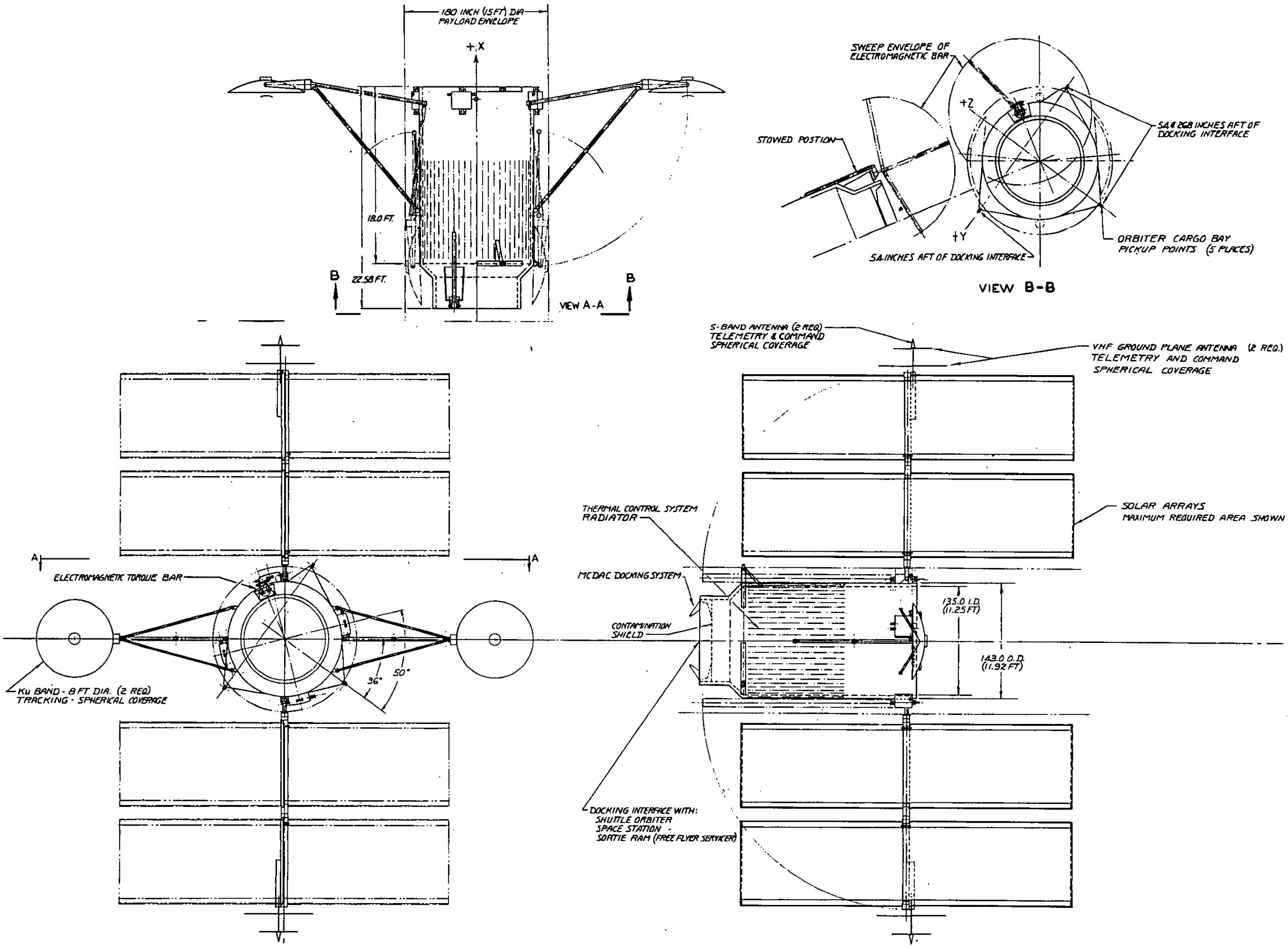


Figure 3-64. Free-Flying RAM General Arrangement

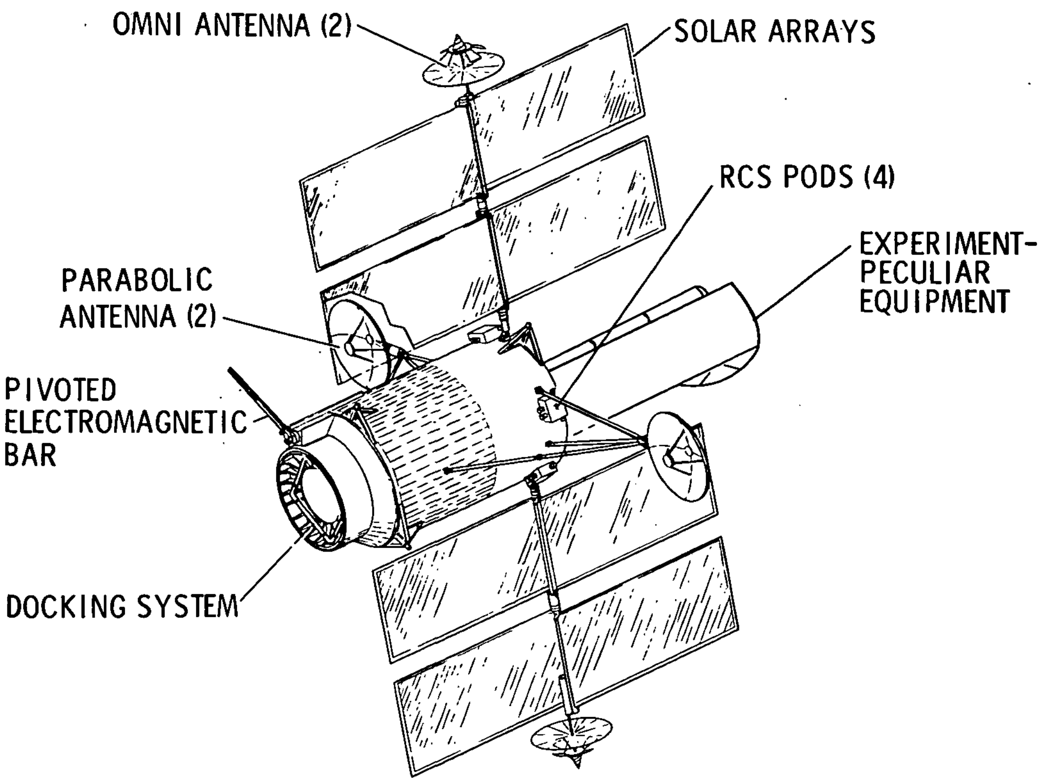


Figure 3-65. Free-Flying RAM Observatory

and 22.58 feet in length. At one end is a standard 102-inch-diameter docking medium and 60-inch-diameter contamination shield. The viewing end is closed by an experiment-peculiar pressure bulkhead structure. Four roll-out solar cell arrays form a dragon-fly configuration for power generation. The propulsion/RCS units are located adjacent to the array and antenna mounts to avoid direct plume impingement on these mounts, the arrays, or the shuttle-attachment fittings. The length of the antenna mount is derived from the requirement to provide coverage with the solar cell arrays deployed.

Characteristics of the baseline free-flying RAM configuration are presented in Table 3-19.

Figure 3-66 is an inboard profile of the free-flying RAM, illustrating the salient features of the design. The payload shown is for stellar x-ray astronomy, A103B. The arrangement provides space and mounting provisions for the electrical power, thermal control, communications, data management, and GN&C subsystems for all free-flying RAMs. Equipment racks are mounted such that they can be unlatched and swung out for access to the pressure wall. The electrical power equipment is located around the inside of the docking tunnel and the freon 21 portion of the thermal control

Table 3-19. Characteristics of Free-Flying RAM Configuration

Parameter	Basic Configuration
Overall Length — In. (ft)	271.0 (22.6)
Constant Section Sidewall Length — In. (ft)	216.0 (18.0)
Internal Diameter — In. (ft)	135.0 (11.25)
Internal Volume — ft^3	2050
External Diameter, Meteoroid/Radiator Shield — In. (ft)	143.0 (11.9)
Support Fittings, Orbiter	5
Hatches	1 at 60 in. diameter
Electrical Power Subsystem	
Solar Array Area, Shuttle Supported — ft^2	1010
Solar Array Area, Station-Supported — ft^2	870
Distribution Voltage	28 Vdc
Batteries	6, each rated at 36 amp-hr
Thermal Control System	
External Loop	Freon
Internal Loop	Water
Radiator Area — ft^2	370
Maximum Heat Capacity: Radiator — kW/hr	3.5
EC/LS	Supplied by sortie RAM or space station
Propulsion (RCS)	
Shuttle-Supported	
No. of Engines	24
Thrust per Engine — lbf	25
Propellant	Hydrazine
Station-Supported	
No. of Engines	32
Thrust per Engine — lbf	25
Propellant	Hydrazine
Communication	
Shuttle Supported	
Telemetry & Tracking	Ku band/TDRS
Command	VHF/TDRS
Shuttle to Free-Flying RAM, Telemetry & Command	S-band
Station Supported	
Telemetry & Tracking & Command	Ku band to station
Data Management	
Data Handling	Tape recorder — 1.8 10^{11} bits
Processing	Central computer
Acquisition & Command Distribution	Full multiplex
Checkout, Fault Isolation	Integrated with DMS
Controls and Display	
Shuttle-Supported	Supplied at sortie RAM
Station-Supported	Supplied at space station

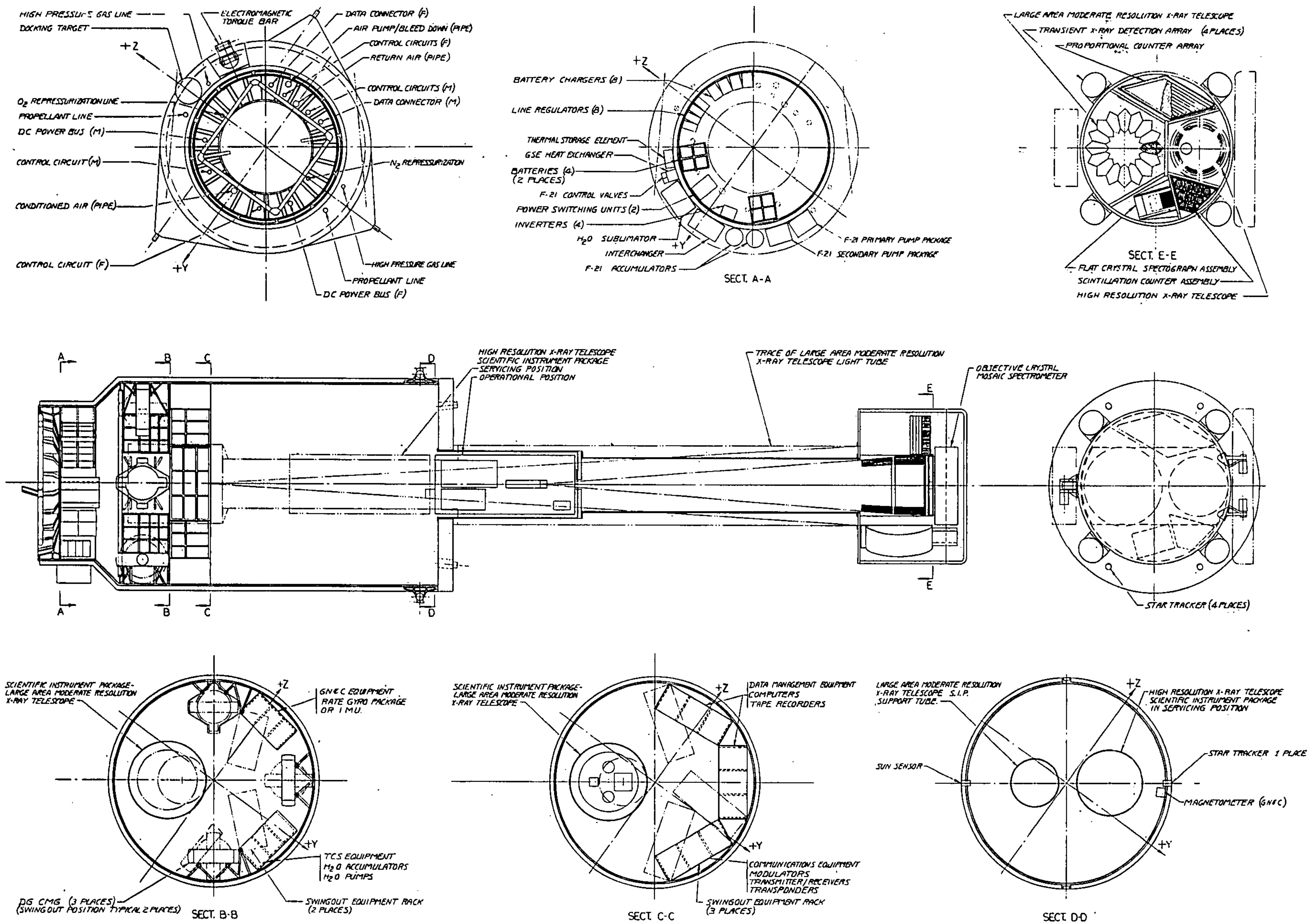


Figure 3-66. Free-Flying RAM Inboard Profile

system is mounted on the exterior surface of the tunnel. Three orthogonally oriented double-gimbal CMGs are located at the forward end of the constant section, with two swingout equipment racks containing the GN&C equipment and the water pumps and accumulators for the thermal control system.

Just aft of the directional CMGs are three swingout equipment racks containing the data management and communications equipment. The CMGs and equipment racks are arranged at one side of the constant-section cylinder to provide maximum space along the opposite side for the long payloads. Electric power is provided by flexible roll-out solar cell arrays; nickel-cadmium batteries provide the required energy storage with long life and high cycle capacity.

Spherical communication coverage is provided by VHF and S-band antennas that retract into cylindrical shapes mounted at the top of each solar array mast. The eight-foot-diameter Ku-band paraboloidal antennas are stowed along the forward end of the free-flying RAM and erected on a tripod to the height required to provide spherical coverage while the solar arrays are oriented in their most adverse position. In the station-supported free-flying RAM configuration, the eight-foot antennas are replaced with two 2-foot rigid dishes.

A complete dual-loop (water/freon) thermal control subsystem is contained in the free-flying RAM. The available radiator area is about 370 square feet. Any unique thermal control requirements (e.g., requiring precise temperature control over large surfaces or cryogenics for sensors) are considered experiment-peculiar and will be provided by the payload.

The RCS/propulsion subsystem operates with the GN&C subsystem and provides the propulsive capability for vehicle orientation, stationkeeping, rendezvous, and docking/undocking as needed by the associated operating mode. Twenty-four 25-lbf hydrazine thrusters provide three-axis translation and rotation to the shuttle-supported free-flying RAM. The RCS system consists of four independent replaceable tank and thruster units spaced at 45 degrees around the +X end near the solar arrays and antenna mounts.

Free-flying RAMs operate in an unpressurized condition. When man-tended, as for servicing, repressurization and EC/LS functions are provided by the servicing vehicle. The free-flying RAM provides only air distribution and circulation plus work positions, mobility aids, and restraints for two to four men.

The GN&C subsystem provides a pointing accuracy of ±1 arc-second and a stability of 0.5 to 1.0 arc-second per observation period. Addition of reaction wheels has the potential of improving stability to 0.005 arc-second per observation, which is required for some payloads.

An electromagnetic torque bar for momentum desaturation of the CMGs is located at the docking end and is provided with a three-degree-of-freedom mount for alignment relative to the earth's magnetic field.

3.3.1.2 Space-Station-Supported Free-Flying RAM. Major differences between the station-supported and the baseline shuttle-supported free-flying RAMs are with respect to propulsion/RCS and communications. The station-supported free-flying RAM has an integral propulsion/RCS consisting of thirty-two 25-lbf thrusters. Eight of these thrusters and the propellant tankage for the complete system are located around the docking tunnel. The eight-foot-diameter communications antennas are replaced by two-foot dishes.

3.3.1.3 14-Foot-Diameter versus 12-Foot-Diameter Free-Flying RAM. The possibility of using a 14-foot-diameter, which is common with the pressurized RAMs, was investigated, but it was concluded that this results in untenable design compromises to the external subsystems because of the limiting 14-foot-diameter shuttle cargo bay envelope. This leaves only six inches clearance outside of the radiator/ meteoroid shielding. The solar cell arrays, RCS, and eight-foot-diameter antennas present clearance problems. For example, the retracted solar cell array cylinders would require two troughs in the primary pressure wall over nearly the entire length and considerably reduces the radiator area. An alternative would be to telescope the solar array mount to stow the arrays at the viewing end of the free-flying RAM (aft end of cargo bay), but this intrudes into the area occupied by the shuttle orbital maneuver subsystem.

3.3.2 STRUCTURE. The free-flying RAM structure shown in Figure 3-67 is a 135-inch-diameter cylinder 216 inches long. Attached to the forward end of this cylinder is a 45-degree conical bulkhead, a 23.5-inch-long 102-inch-diameter adapter section, and the docking adapter.

Experiment-peculiar structure is bolted to the aft end of the cylinder at the 135-inch-diameter ring. The five orbiter attachment fitting assemblies the RCS motor packages, the antennas, and the solar arrays are bolted to the cylindrical section.

There are provisions for mounting the power system equipment in the adapter section. Other subsystem equipment and CMGs are truss mounted and housed internally on the module cylinder. Internal subsystem equipment is also rack-mounted to the cylinder sidewall.

Docking Adapter

The docking adapter used on the free-flying RAM is the design developed for the space station and used for reference on all RAM elements. It is an integrally machined adapter section made from a 2219-T852 Al-alloy ring forging 102 inches

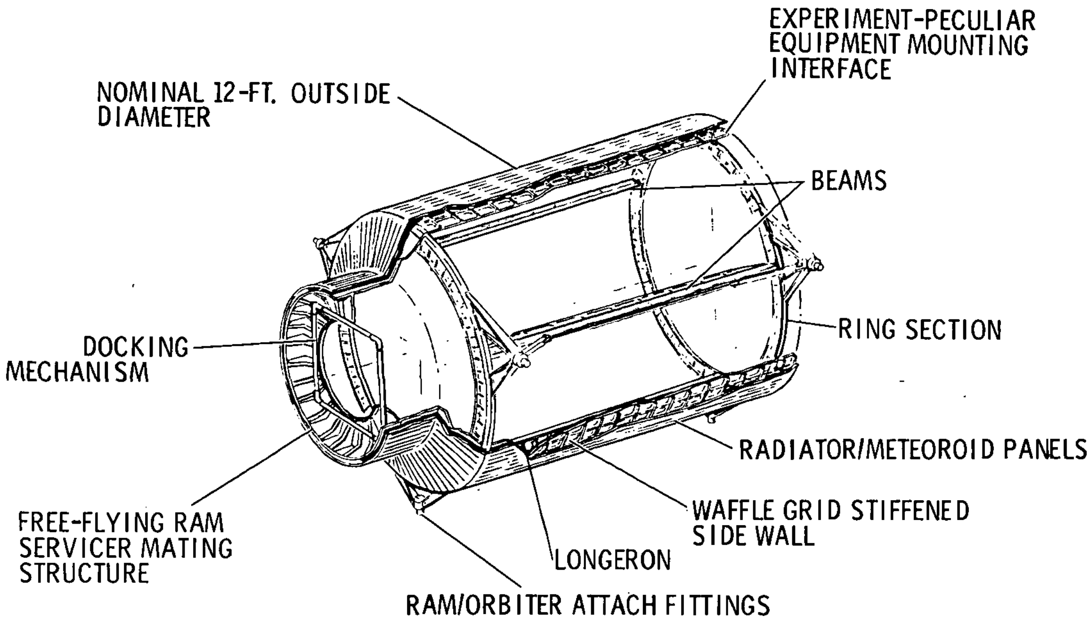


Figure 3-67. Free-Flying RAM Structure

in diameter and 15 inches long. It houses the androgynous docking system, which used a square docking frame. The docking frame is manipulated with eight hydraulic/ air attenuator actuators and has a latching system with provision for 12 active latches each side of the interface. It incorporates a 98-inch-diameter inflatable seal at the interface. It also has a nominally 60-inch diameter hatch on the centerline. The docking adapter can be attached to the conical bulkhead at the 102-inch diameter using a bolt-ring flange and static seal.

102-Inch-Diameter Adapter

Except for being 23.5 inches long, this adapter is identical to that used on the sortie RAM. It is made from a one-piece roll-ring forging of 2219-T852 aluminum alloy as an integrally machined thick-walled cylinder with wide end-bolt flanges.

Cylindrical Sidewalls

The cylindrical sidewall consists of three 209-inch-long panels rolled to the 135-inch inside diameter and a separate ring section 7 inches long. It has two primary end rings, each 8 inches deep with I cross sections. The 7-inch-long ring section is made from a ring forging of 2219-T852 aluminum alloy and is used to attach the aft primary ring and the orbiter fittings and acts as the splice joint to the experiment-peculiar structure. It is welded to the three cylindrical panel sections.

Two longitudinal I beams are welded into the cylindrical section about 15 degrees above the horizontal centerline. The beam at the -Y axis, the left side looking forward, is 12 inches deep; the other beam is 3 inches deep. A longeron is welded into the cylinder at the -Z bottom centerline. The three cylindrical panels span between the beams of the longeron on the bottom centerline. The cylindrical panels are made with integrally machined grid stiffeners. This waffle structure is identical to that used on sortie RAMs and RAM payload modules and consists of a 5-inch 90-degree square grid with the stiffeners facing outside the module. The depth of the grid is 1 inch, the stiffeners are 0.050 inch thick, and the skin thickness is 0.070 inch. The cylindrical panels, the primary rings, the horizontal beams, and the ring section are made from 2219 aluminum alloy.

Conical Bulkhead

This bulkhead provides the transition between the 135-inch-diameter cylindrical sidewall and the docking adapter. The bulkhead is in the form of a 45-degree cone. It is made from three segments welded together at a longitudinal seam; each segment consists of an 0.055 inch skin that has longitudinal integrally machined blade stiffeners 1 inch high by 0.10 inch wide. The attachment to cylinder is a welded joint at the forward end ring. The 102-inch-diameter interface is a bolt ring welded to the cone. These bulkheads are made from 2219 aluminum alloy.

RAM/Orbiter Attachment Fittings

The attachment fitting concept used on the free-flying RAM is the five-point reaction statically determinant system used on the sortie RAMs. The differences lie only in the physical size of the fittings and diameter of the cylindrical sidewall.

This design uses two tripod fittings at the forward +Y and -Y and one at the rear -Y location. Two A-frame fittings are located at the forward and aft -Z positions. A beam is used to accept the local moment induced by the longitudinal load and to react this load at the two end rings. This beam has an I section and its outer flange is welded into the cylindrical side wall forming a splice joint for the machined panels. The beam is 12 inches deep at the load application location and tapers to 8 inches deep at the forward end and 4 inches deep at the aft end. An integral blade is machined on the surface of the outer flange of the beam and is used to attach the machined link that forms the third leg of the tripod fitting. Each of the tripod fittings is made from a machined steel A-frame, with a machined link as the third leg. This link is attached to the A-frame through a simple clevis and to the upstanding blade of the beam through a knuckle or double clevis attachment.

In addition, there is a small beam placed at the +Y location. This beam gives symmetry to the cylindrical structure and provides a structural tie for the orbiter fittings, which will induce small loads in the longitudinal direction.

Environment Protection

Except for the dimensions of the panels, this system is identical in all respects to that used on the sortie RAM.

The radiator/meteoroid bumper is made from a sandwich of 0.016-inch outer and 0.010-inch inner aluminum skins bonded to a high-temperature polyurethane foam core. The radiator/bumper panels cover the cylindrical portion of the module and are split into sets of eight 45-degree sections. Each panel contains fluid passages installed longitudinally; four of these are integral with an I-shaped extruded stiffener and the others in a D-shaped extrusion bonded within the sandwich. The fluid passages are connected at the ends of the panels in a radial direction. These connections are made through a valving system that controls the fluid flow in the eight panels. Each panel is about 4.5 by 18 feet and is attached to the sidewall at both ends through hinge fittings that allow the panel to expand or contract under temperature variations.

Environmental protection of the conical bulkhead uses the same sandwich construction as the cylindrical section, but without the radiator tubes.

Access covers are made in eight sections and are attached to cylindrical section at the kick rings and have slip joints. These covers may be removed to expose the radiator manifold and the hoist fitting attachments. Other access panels on cylindrical section are removed to expose the ground handling and transportation fittings.

The entire surface area of the module, with the exception of the docking interface, is covered with 45 layers of Super Floc insulation. The insulation is supported on fiberglass clips and attached to the bulkheads and the cylindrical sidewall by nonmetallic fasteners.

3.3.3 <u>ENVIRONMENTAL CONTROL/LIFE SUPPORT (EC/LS) SUBSYSTEM.</u> The EC/LS subsystem provides the functions shown in Figure 3-68 for two payload crewmen during on-orbit servicing. Since the free-flying RAMs operate unpressurized and unmanned during experiment operations, EC/LS functions are required only when the free-flying RAM is being serviced by the sortie RAM or the space station crew. During the servicing period, primary EC/LS functions are provided by either the sortie RAM or space station with the free-flying RAM supplying atmospheric circulation, module pressure relief, and storage space for special life support equipment. The free-flying RAM EC/LS subsystem schematic is shown in Figure 3-69 and its physical characteristics in Table 3-20.

Atmosphere Circulation Assembly

The free-flying RAM air supply is provided from the sortie RAM or space station. The air circulation assembly consists of distribution ducting and two fans transferred

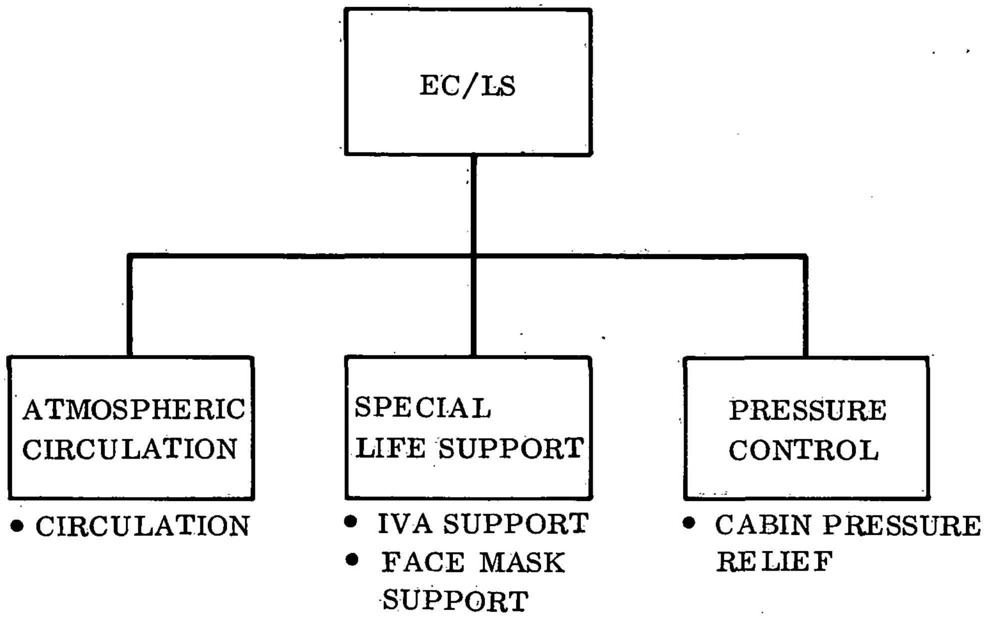


Figure 3-68. Free-Flying RAM Major EC/LS Subsystem Assemblies

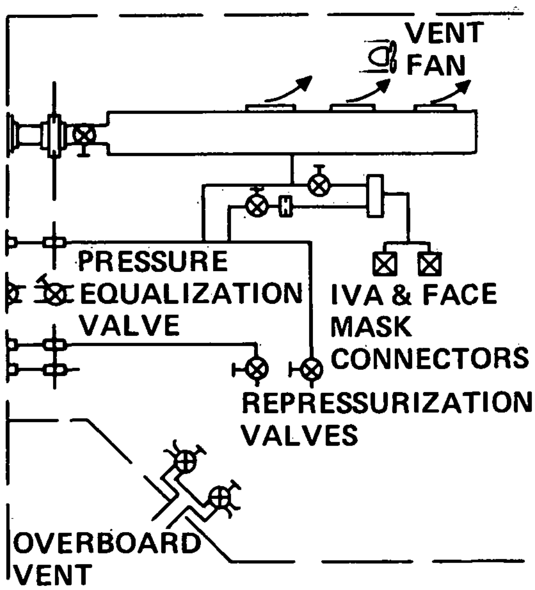


Figure 3-69. Free-Flying RAM EC/LS Subsystem Schematic

Table 3-20. Free-Flying RAM EC/LS Subsystem Physical Characteristics

Function	Weight (lb)	Volume (cu ft)	Power (Watts)
Atmosphere Revitalization	48	9.0	30
Pressure Control	17	0.1	
Special Life Support	8	0.2	10
Totals	73	9.3	40

from the supporting module to the free-flying RAM. Filtering and carbon dioxide, odor, and humidity control are accomplished in the sortie RAM or space station.

Pressure Control

Minimum pressure control equipment is required for the free-flying RAM. Nitrogen pressure is required to operate the humidity condensate cyclic accumulators and module pressure relief is provided when the pressure exceeds 16 psia or the negative differential pressure within the module exceeds 0.5 psi.

Special Life Support Assembly

The special life support assembly is composed of two subassemblies that provide IVA and face mask support. Connections for two IVA umbilicals are required. Support is limited to purge flow of oxygen to IVA suits in the event of contingency depressurized or contaminated cabin operations. Oxygen flow is activated manually.

3.3.4 ELECTRICAL POWER SUBSYSTEM (EPS). The primary functions provided by the EPS are power generation, conversion, control, and distribution.

Power Generation

Solar arrays are used for prime power generation. In addition to load power requirements, the sizing of solar arrays is a function of orbital parameters because the largest degradation is due to radiation damage (Figure 3-70).

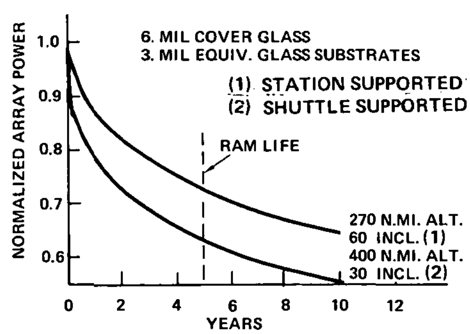


Figure 3-70. Solar Array Output Versus Time

Accordingly, the solar arrays sizes range from 510 to 870 square feet for station-supported operations and 590 to 1010 square feet for shuttle-supported. The array is a flexible rollout type developed by Hughes and already in flight operation. Figure 3-71 illustrates the basic rollup system. The free-flying RAMS feature dragon-fly systems with two tandem drums on each side; these extend four array panels on each side of the vehicle. The dragon-fly arrangement minimizes the length of the arrays for large areas. Figure 3-72 illustrates the retracted and deployed array configurations. The solar cells are 2 by 4 cm, 2 ohm • cm, 0.008-inch-thick N/P silicon. The cover glass is 6-mil fused silica with anti-reflection and blue filter coatings. Array panels are divided into modules of 3.18 by 7.5 feet so that incremental changes in array power can be

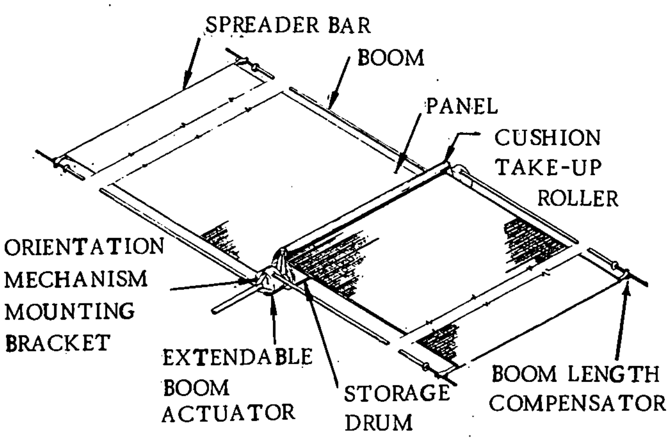


Figure 3-71. Hughes Rollout Array System

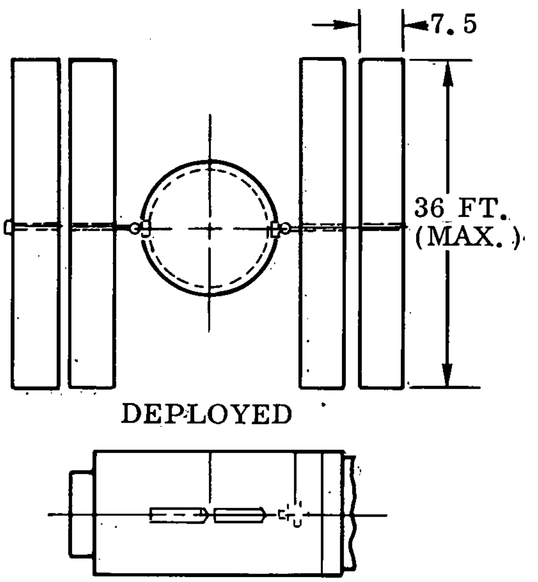


Figure 3-72. Free-Flying RAM Solar Array Configuration

performed without major redesign of the array. Drum size, boom length, and orientation mechanisms are common for all free-flying RAMs to minimize redesign.

Power during periods of eclipse is provided by nickel-cadmium batteries. The batteries are rated at 36 amp-hr (except for LST, which has a 30 amp-hr battery) and sized for a depth of discharge (DOD) of about 20 percent. This DOD results in minimum weight to orbit for such a system.

Distribution, Conditioning, and Control

The distribution concept employs spacecraft-proven technology of 28 vdc and 115/200 vac, 400 Hz distribution. Circuit protection and switching design is based on space shuttle technology and uses solid-state power controllers for loads up to ten amps. For larger loads, hybrid power controllers are used. These units use solid-state elements for control and protection and electromechanical elements for power switching. A generally centralized power conditioning concept is used because it was demonstrated to be more cost effective and to require less weight and volume.

As shown in Figure 3-73, the EPS provides three independent power channels: a main bus and two essential (emergency) buses plus control ability. The main bus powers all normal operations including an experiment bus, and the essential buses provide the capability of offsetting two failures. The electrical monitoring and control package provides for fault sensing and mode selection by controlling the bus contactors. Provisions are included to interface with the orbiter, sortie RAM, space station, and ground support equipment.

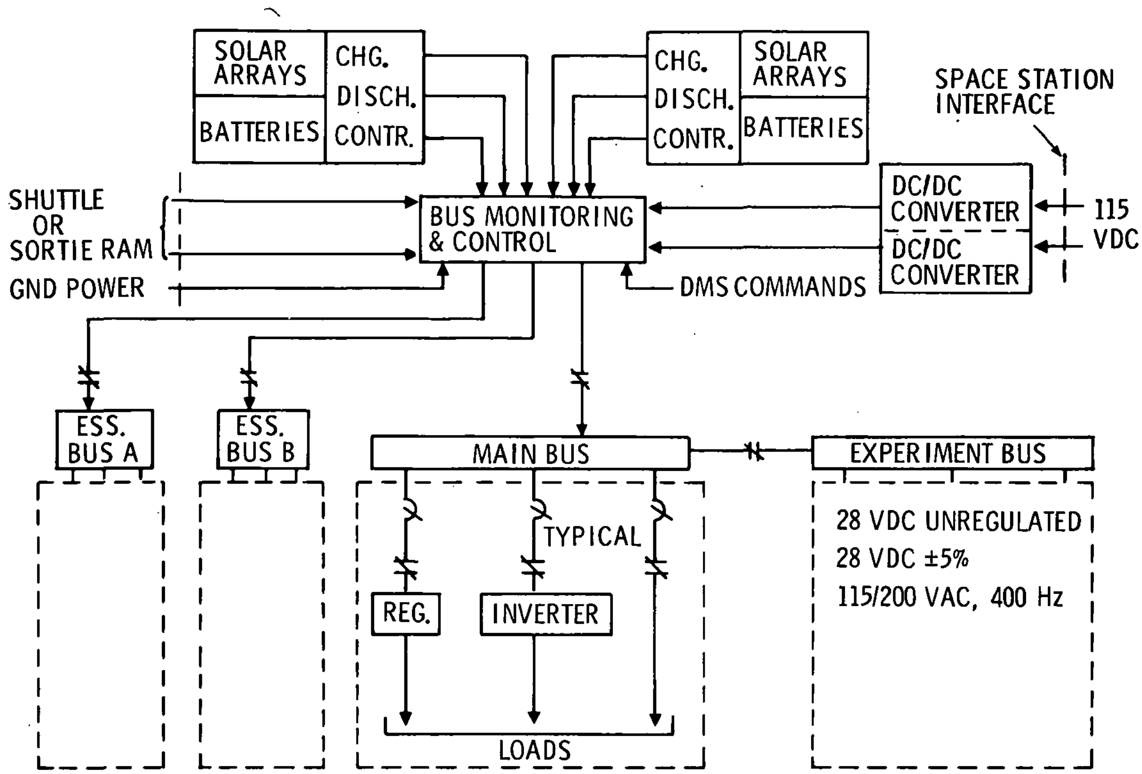


Figure 3-73. Free-Flying RAM EPS Schematic

3.3.5 HABITABILITY. Only limited habitability items are permanently installed aboard the free-flying RAMs supported by the shuttle and the space station, since man's participation in the free-flying RAM operation is limited to servicing operations at six month intervals. Items identified for habitability include mobility aids and restraints (Figures 3-74 and 3-75). However, other habitability items are necessary to support crew task performance during the free-flying RAM delivery and retrieval and servicing operations. These items are provided by the shuttle (Figure 3-74) for delivery and retrieval and by the shuttle or the space station for servicing.

3.3.6 COMMUNICATIONS. Three communication operational modes are possible: shuttle-supported (TDRS), space-station-supported, and direct ground network. The allocation of communication support is shown in Table 3-21.

Data relay is via TDRS using two 8-foot Ku-band dishes (shuttle supported), two 2-foot Ku-band dishes (station supported), or by S-band directly to the ground network (LST). Shuttle-and station-supported wideband and high-rate digital channels are 50 MHz and 10 Mbps. Ku-band tracking and VHF telemetry and command information is relayed via TDRS for the shuttle-supported free-flying RAM; similarly, a unified S-band transponder supports telemetry and control for direct-ground-network supported operation. Wideband data relay transmitter power requirements are between 2 and 50 Watts.

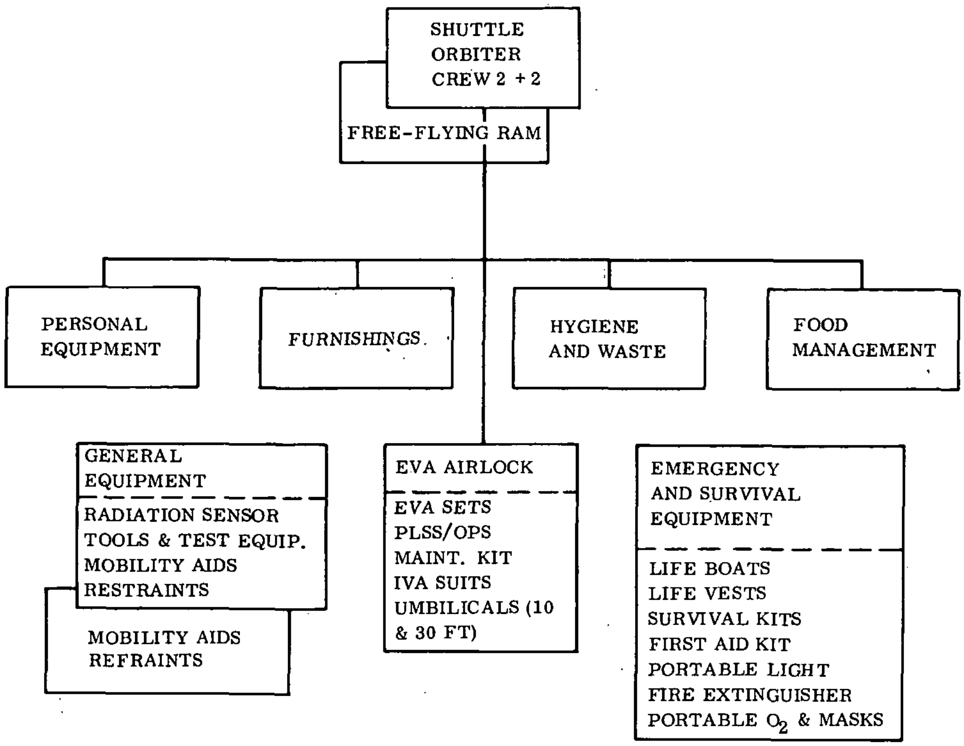
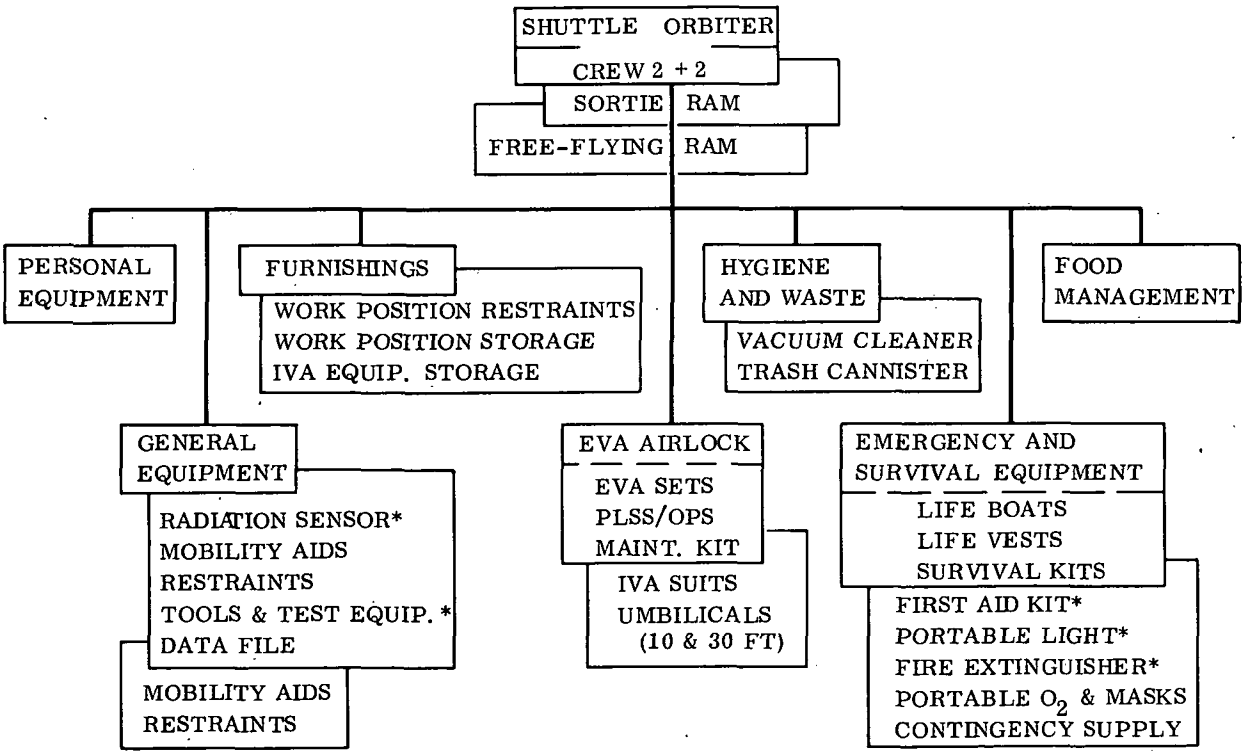


Figure 3-74. Free-Flying RAM Delivery and Retrieval Equipment Requirements



*CARRY ON AND STOW ABOARD THE FREE-FLYING RAM DURING SERVICING OPERATIONS.

Figure 3-75. Free-Flying Servicing Equipment Requirements

Table 3-21. Allocation of Free-Flying RAM Communications

Mission Mode	Data	Voice	Command	Tracking
Shuttle Supported	Wideband data via Ku-band/ TDRS. Buffer storage required on free-flying RAM. VHF telemetry to TDRS S-band to orbiter*	Not required except during servicing. Provided by orbiter.	VHF/TDRS relay S-band from orbiter*	Ku-band/TDRS VHF ranging to/from orbiter*
Station Supported	Wideband data via Ku-band to space station. Buffer storage required on free-flying RAM. Ku-band telemetry to space station. S-band to orbiter*	Not required except during servicing. Provided by servicing vehicle.	Commanded by space station or by a space station relay via Ku-band link. S-band from orbiter*	Range and range-rate tracking provided by space station. VHF ranging to/from orbiter*
Direct Ground Network Supported (LST)	Wideband data via S-band/ ground network. Buffer storage required on free-flying RAM. S-band telemetry to ground network S-band to orbiter*	Not required except during servicing. Provided by orbiter.	Command by S-band/ ground network S-band from orbiter*	S-band/ground network VHF ranging to/from orbiter*

*Required to provide orbiter recovery of free-flying RAMs. (Data is low-rate telemetry.)

The maximum range for the station-supported mode is 245 n.mi. Programmed tracking (0.1 degree accuracy) with a biaxial drive system is used with the 8- or 2-foot Ku-band dishes. Two antennas provide spherical coverage. A minimum outage time of 5 minutes per orbit can occur when a single 8-foot antenna must handover between TDRS satellites located in the same hemisphere.

During rendezvous, orbiter telemetry and control is provided by a unified S-band transponder and ranging by a VHF ranging transponder. A pair of erectable VHF/S-band integrated antennas located at the end of the solar array mast provide spherical coverage for telemetry, command, and ranging in any of the three mission modes.

3.3.7 DATA MANAGEMENT AND ONBOARD CHECKOUT SUBSYSTEM (OCS). The basic data-handling approach is buffer digital magnetic tape storage and relay to ground. The buffer is a magnetic tape recorder that accepts data at high rates and, by tape speed reduction and demultiplexing, provides an output rate of 10 Mbps for transmission. Experiment data volume ranges from 9×10^8 to 5.1×10^{10} bits/orbit, with rate requirements between 5 Mbps and 1.24 Gbps. The higher rate requirement necessitates the use of an advanced magnetic tape recorder design. An existing upgraded vision of the Skylab tape recorder is used to satisfy the lower requirement.

Near-real-time transmission of wideband analog spotting camera video data (0.14 to 8.2 MHz) to the ground is required. A full multiplex digital interface data acquisition and command distribution system is used to receive and transmit low-rate information

over a full multiplex wire, decode instructions into functional commands, and provide a buffer for data generated by and sent to experiment sensors and subsystems (Figure 3-76). Typically, as many as 2200 signals will be controlled. Interface terminals, low-rate formatters, and command decoders tie into the free-flying RAM communications system for telemetry and command. A high-rate digital formatter and multiplexer controls the buffer digital tape recorder. The analog multiplexer and switch controls the near-real-time transmission of analog wideband data. Twenty-one digital interface units (DIUs) are used to provide the redundancy required to meet the failure modes and effects (FMEA) criteria.

Control, monitor, and automatic checkout of all subsystems and experiments is by a centralized computer configuration. Floating point hardware is used and three computers satisfy FMEA criteria. Software implementation features a modular structure under control of a hybrid executive. A separate software package is used for experiments and generalized for all subsystems. A higher-order language, selected from those under development, is proposed to reduce coding effort and (for simple debugging) easier verification and better documentation.

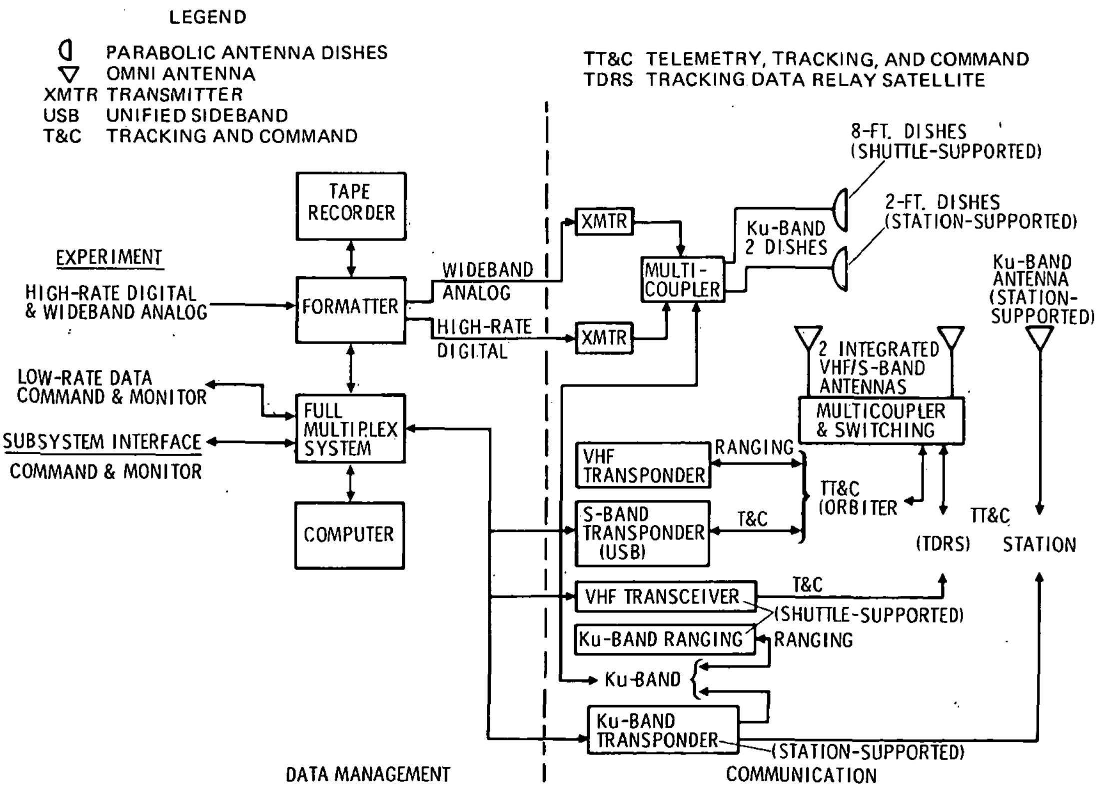


Figure 3-76. Free-Flying RAM Communications/Data Management Subsystem Schematic

OCS for the free-flying RAM is a semi-autonomous, flexible, job-oriented system. It performs highly organized, repetitive functions requiring data processing (such as status monitoring) automatically while permitting crew participation from the space station or ground in those functions performed periodically or on an as-needed basis (such as fault isolation, redundancy switching, and checkout). This versatility in applying degrees of automation to suit functional need is further extended to include the differences between the free-flying RAM subsystems and the experimental equipment.

The OCS (Figure 3-77) uses the computer, data distribution system, and interfacing units. It supplies a stimuli generator to activate subsystems for checkout and fault isolation. It also provides a caution and warning (C&W) logic module, which monitors onboard caution and warning conditions and interfaces with orbiter, sortie RAM, or space station during delivery and servicing. This function is performed concurrent with, but independent of, other checkout functions by the OCS. C&W signals are generated by the logic module and distributed by hardwire to all display and sounding alarms located in the pressurized area and to the space station, sortie RAM, or orbiter during servicing or delivery.

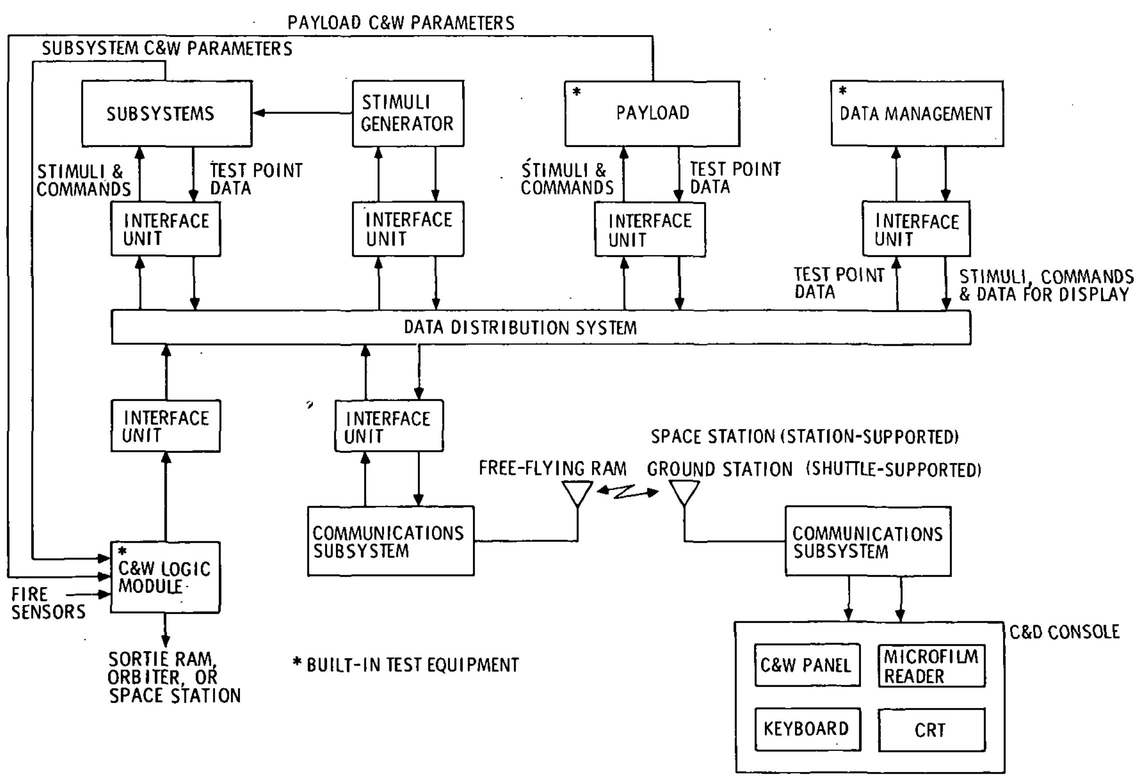


Figure 3-77. Free-Flying RAM OCS

When the free-flying RAM is operating on-orbit in an unmanned condition, the C&W logic module outputs are distributed to the communications subsystems for transmission either to the ground station (shuttle-supported mission mode) or to the space station (station-supported mission mode) for display and subsequent action.

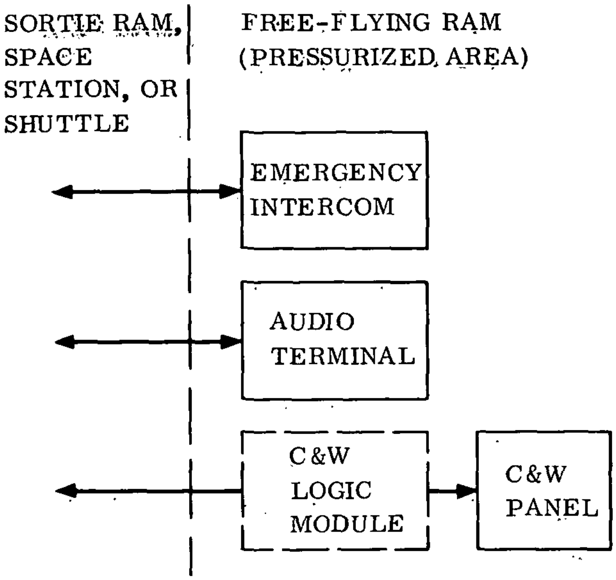


Figure 3-78. Free-Flying RAM Audio and C&W Functions

3.3.8 CONTROL AND DISPLAY (C&D) SUBSYSTEM. The functions provided by the C&D subsystem for the free-flying RAM are 1) audio distribution and 2) caution and warning displays and alarm. The primary C&D for servicing the free-flying RAM is provided by the sortie RAM or space station; the third C&D station in the orbiter provides support for delivery missions.

The audio communications and caution and warning panels are provided as illustrated in Figure 3-78. Provisions are made to interface with the sortie RAM, space station, or orbiter.

3.3.9 GUIDANCE, NAVIGATION, AND CONTROL (GN&C) SUBSYSTEM. The shuttle-launched, shuttle-serviced free-flying RAM is covered first. The incremental impact of the other free-flying missions on GN&C is then described.

The driving requirements consist of all-attitude pointing in a stellar-referenced orientation with stringent accuracy and stability for Astronomy payloads. These and other intrasubsystem pointing support requirements are given within the selected system description. Contamination, slew rate, and acceleration requirements are as shown in Table 3-22. The reaction control subsystem is not used during experiment operations because of the contamination requirement. The vehicle size treated is 120,000 slug-ft^2 pitch/yaw/moment-of-inertia, with roll at about 0.1 pitch/yaw.

All-attitude sensing to 30 arc-sec accuracy is provided by fixed-head star trackers used with a strapdown rate gyro package (Figure 3-79). This capability is used to position the free-flying RAM within the acquisition capability of the experiment-integral aspect sensors. Experiment time pointing error signals are sent to the digital processor to control position of and to stabilize the vehicle. The torquing complement consists of three double-gimbal CMGs, which stabilize the free-flying RAM body to 0.5 arc-sec. More stringent pointing requirements, beyond the CMG threshold capability, are satisfied by either an experiment-integral vernier of image motion compensation (IMC) or the modular addition of small trimming reaction wheels shown in Figure 3-79.

Table 3-22. Free-Flying RAM Integral GN&C Requirements

Requirement	Value
Pointing Augmentation	
Acquisition Accuracy	$\pm$(0.25 deg - 30 arc-sec)
Observation Accuracy	$\pm$(0.5 deg - 1 arc-sec)
Observation Stability	$\pm$(0.5 deg - 0.5 arc-sec)
Observation Time	(0 to 5) hr
Slew Rate, Acceleration	6 deg/min, 6 deg/min^2
Orbit Cleanliness	
Particulate	(10^3 to 10^4) particles/meter^3
Pressure	(10^{-6} to 10^{-7}) Torr
Magnetic	2 Gauss

Desaturation of CMG momentum accumulation is provided by the magnetic torquer, which consists of a double-pivoted long (7 to 10 feet) bar electromagnet. Continuous desaturation torque is provided via interaction with the earth magnetic field (measured by the magnetometer).

The target/stadia is a passive device, derived from the Apollo program, to support shuttle-active manual docking.

The equipment includes redundant module assemblies, critical to module recovery operations, to offset any credible combination of two component failures. Additional selective redundancy on star tracker, rate gyro package (internal), and CMGs to continue experiment operations after a failure is also provided to minimize the probability of an unscheduled shuttle service trip.

For station-supported and expendable-booster-launched free-flying RAMs, the ΔV applied by the reaction control subsystem and the free-flying RAM rotary state must be known. This incremental requirement is satisfied by adding accelerometers to the rate gyro package. For station-supported free-flying RAMs, the addition is used in active stationkeeping, rendezvous, and dock, all of which is directed by station-integral guidance and navigation. For free-flying RAMs launched by expendable boosters, the addition is used to monitor the execution of the ΔV imparted by the reaction control subsystem in an orbit circularization maneuver.

Major trade issues were concerned with CMG, magnetic torquer, and star tracker selection. A strapdown rate gyro package was selected relative to a gimbaled

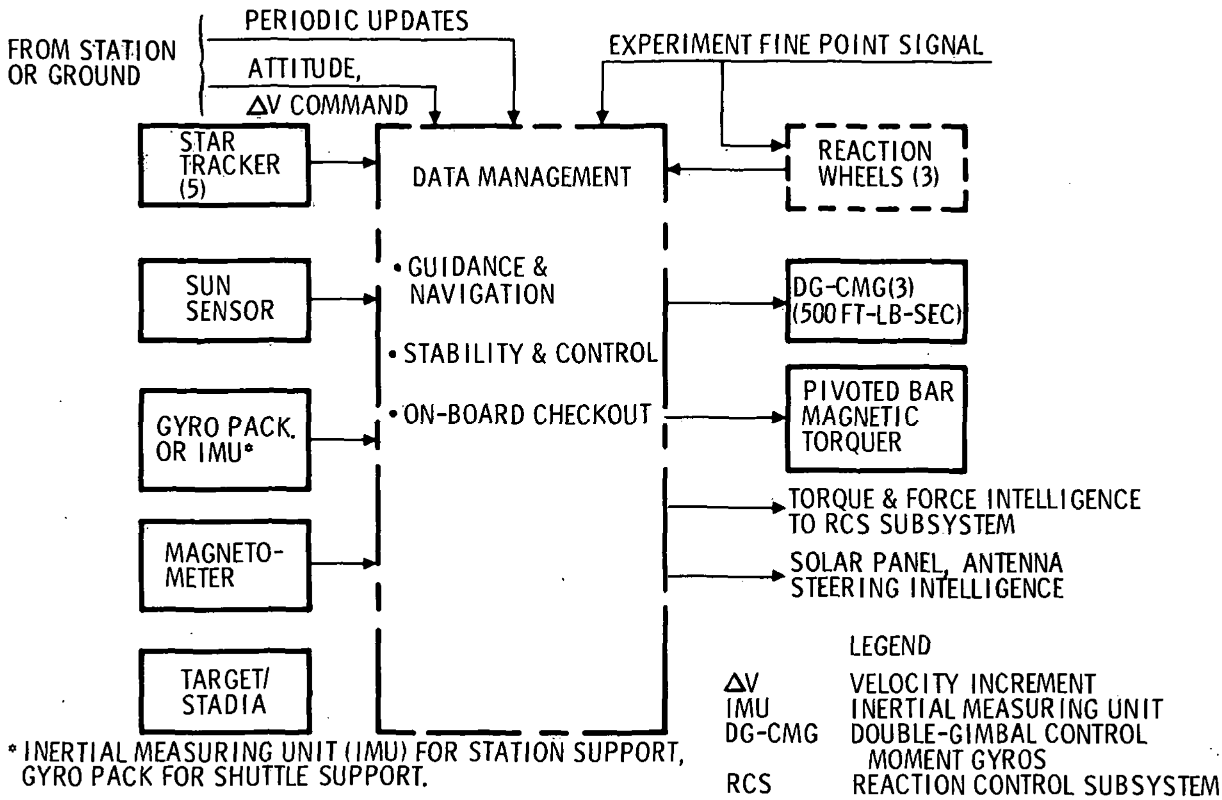


Figure 3-79. Free-flying RAM GN&C Configuration

platform because of its better size, weight, and cost. High-maneuver-rate measurement inherent in a gimbaled platform is not required for this application.

A system with three doubled-gimbaled CMGs was selected over a five single-gimbal system because of increased performance over a spherical momentum envelope, essentially no singular torque output points, favorable size, and weight.

Because of the large size and weight of the magnetic torquer, the increased complexity of the pivoted type was selected. Both types are new units.

Because of increased reliability and resultant savings in total system cost, a fixed-head star tracker was selected in lieu of a gimbaled unit. An increased sensitivity unit, (i.e., the capability for imaging 6th magnitude stars compared to present capability of 4th magnitude imaging) plus pattern recognition on the corresponding star population is required. However, based on the present state-of-the-art and the projected improvements in star tracker sensitivity, it is expected that the desired improvements will be available in a time frame compatible with RAM requirements.

3.3.10 THERMAL CONTROL SUBSYSTEM (TCS). During normal operations, the free-flying RAMs are unpressurized and unmanned. The free-flying RAM TCS (Figure 3-80) uses two fluid systems. Water is used internally because of commonality with the other RAM elements and because of its excellent heat transfer capability. The water transfers heat from all the interior heat sources to an external freon 21 system across an interloop heat exchanger. This heat is transferred to the radiator panels and rejected to space. The freon supply temperature to the intercooler is maintained at a nominal value of 35°F for battery cooling by a radiator bypass control. The warm freon lines are routed close to the propellant tanks and lines to keep the propellant from freezing.

Thermal damping during periods of rapid transients or peaking loads is provided by the thermal storage element (TSE). This element is sized for the reentry condition when neither the radiators nor the sublimator can be used. For the TSE, a phase change material of the paraffin family with a heat of fusion of 90 Btu/lb was assumed. The TSE was sized for 1.5 hours of operation, which includes a 30-minute post landing period prior to GSE hookup.

The sublimator is used for cooling during ascent ($h \geq 100,000$ ft) when the orbiter bay doors are closed. The sublimator has a heat-rejection capability of 74,000 Btu/hr.

The radiator coating selected is a second-surface mirror of fluorinated ethylene propylene Teflon/Ag/Inconel with long-term (5 year) degraded characteristics of absorptance of 0.24 and emissivity of 0.8. Radiator panel bypass valves are required to prevent heat from hot panels getting into the TCS. The radiators are sized for the largest free-flying RAM heat rejection requirement, which is 10,500 Btu/hr. The total radiator area is 375 square feet. Redundancy is provided in both loops by using two independent circuits for each loop. The TCS interfaces with ground coolant supply through the GSE heat exchanger. This supplies cooling during prelaunch and postlanding operational phases.

3.2.11 PROPULSION/REACTION CONTROL SUBSYSTEM (RCS). Free-Flying RAM RCS requirements and design differences are evidenced in four categories of free-flying RAM: shuttle supported, station-supported, Titan III launched, and technology applications. The basic schematics representing each of these categories are presented in Figure 3-81.

In the shuttle-supported free-flying RAM, the RCS is required to provide for docking reactions, tumble capture, and attitude hold. The tumble could occur as the result of an aborted docking of the shuttle to the free-flying RAM with a resultant tipoff. The RCS would then be used to stabilize and reorient the free-flying RAM prior to another attempt at docking. Allowance is also made to stabilize the vehicle by the RCS to provide a backup mode if the CMG system normally used for free-flying RAM attutude hold fails. Propellant is provided for a two-week attitude hold with an RCS

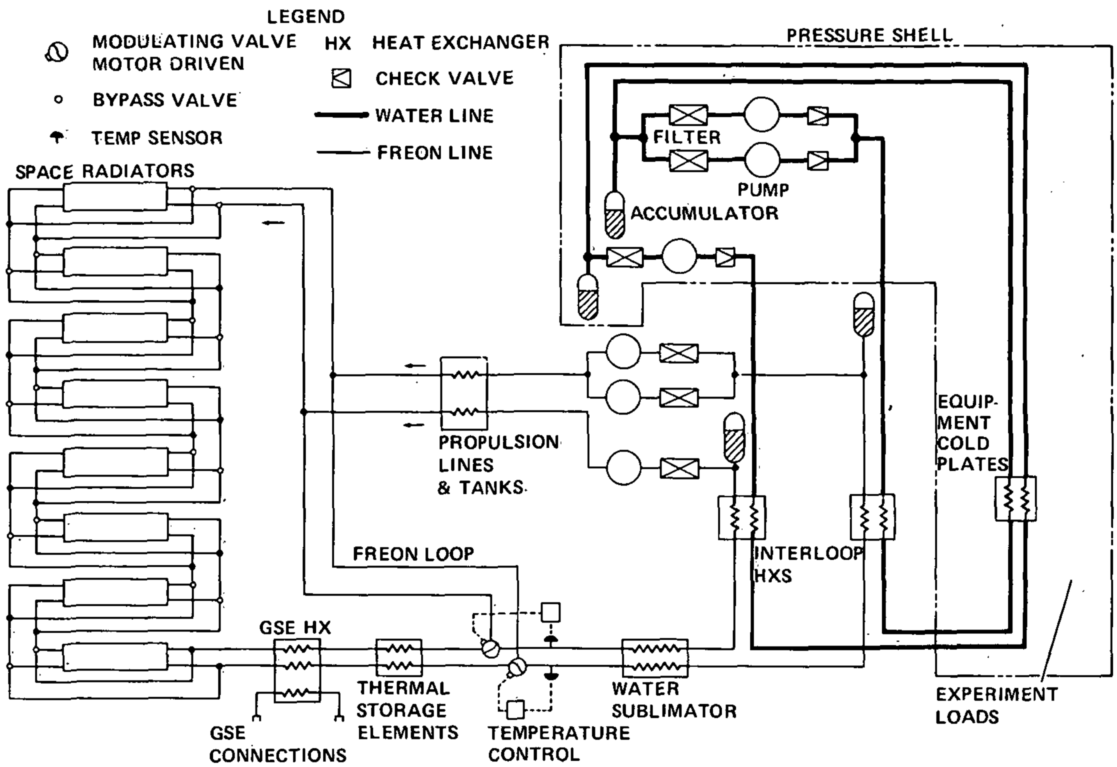


Figure 3-80. Free-Flying RAM TCS Schematic

limit cycle operation prior to retrieval by the shuttle. The propellant quantity is determined by the two-week attitude hold requirement, while the thrust level is dictated by the dock reaction. The required rotary authority of 0.16 deg/sec and the maximum angular momentum of the free-flying RAM vehicles determines the minimum required thrust level. The three functions of the shuttle-supported free-flying RAM vehicles are to be accomplished with roll, pitch, and yaw torque capability. (No displacement capability is required; hence, four clusters of six thrusters each are adequate.)

The RCS is used to provide stationkeeping, rendezvous/departure, and docking/undocking for the station-supported free-flying RAM. The major propellant consumption is associated with stationkeeping due to the six-month operating time requirement without resupply. The thrust level requirement is dictated by the manual docking/undocking maneuver control acceleration requirements. The manual docking requirement is not expected to be a usual type of operation; however, provision for the recommended control authority is provided in the RCS design. Because of the translation requirement, an additional four clusters of two thrusters each are required.

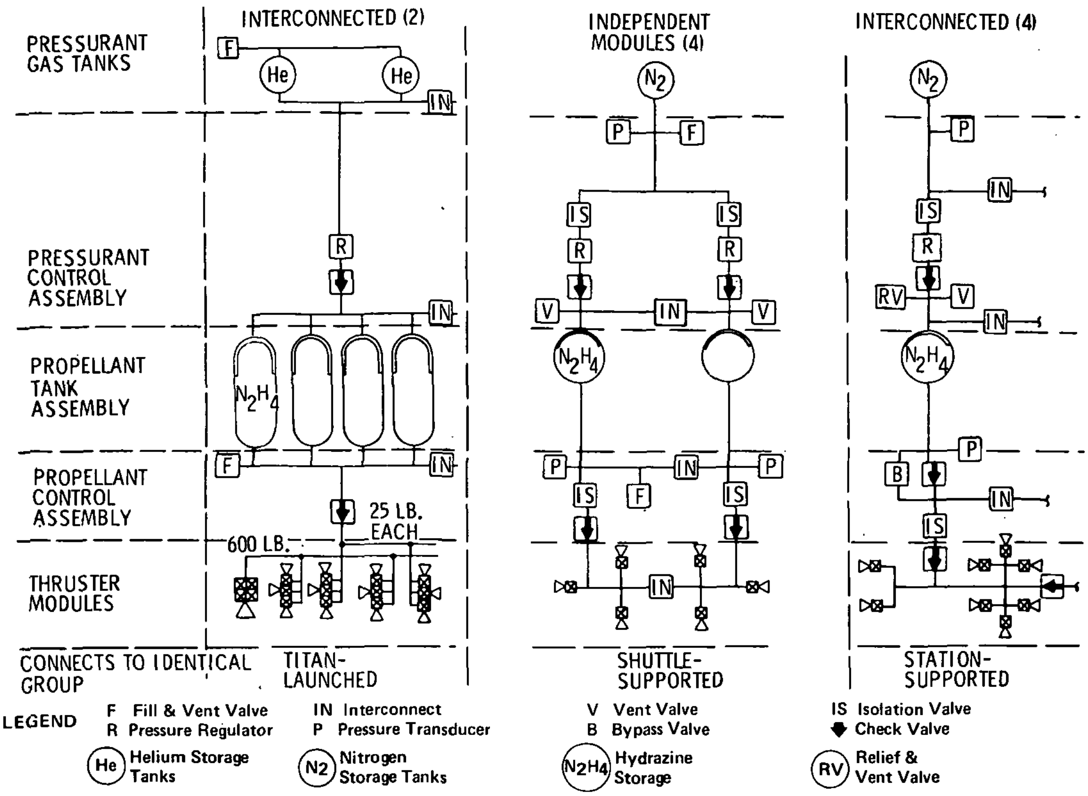


Figure 3-81. Free-Flying RAM Propulsion/RCS Schematics

The principal added requirement for the expendable booster launched free-flying RAM, above those for shuttle-supported RAM, is the ΔV required (521 fps) to transfer the Titan launched vehicle from a 90 by 400 n. mi. orbit to a 400 n. mi. circular orbit.

The free-flying RAM propulsion/RCS design is based on the use of monopropellant hydrazine. The subsystem consists of three basic elements: pressurant, propellant, and thruster systems. Nitrogen pressurant is stored in a high pressure tank, and a pressure regulator maintains the nitrogen pressure in the propellant tank at about 350 psi. A polymeric bladder separates the pressurant from propellant in the tank. The pressurized propellant is then fed to the monopropellant hydrazine thrusters.

The basic RCS arrangement consists of four identical modules, each containing six 25-lbf monopropellant hydrazine thrusters which supply three-axis torques for free-flying RAMs. Eight 25-lbf thrusters are added to the station-supported free-flying RAM because it has an active docking requirement to compensate for substantial differences in center of gravity locations with the different payloads. An orbital circularization requirement exists in the event of a Titan booster launch, and two 600-lbf propulsion thrusters, acting through the spacecraft cg, provide the thrust compatible with a one-burn transfer.

The shuttle-supported free-flying RAM has a small propellant tank requirement of 190 pounds. The propellant tanks are nestled in the four thruster modules, and there are no fluid interconnects between the modules. Resupply of fluids and hardware maintenance are accomplished by replacing the modules. The propellant supply of 750 pounds is normally adequate for a five-year period required for station-supported free-flying RAMs. Resupply of fluids, nitrogen pressurant, and hydrazine monopropellant is accomplished by umbilical transfer. The propulsion/RCS system is integrated into the vehicle, and there are interconnects between the propellant tanks.

All free flying RAMs, whether Titan launched or shuttle- or station-supported, rely on hydrazine monopropellant for their propulsive fuel. The fuel, selected by virtue of a trade study finding, is stored in positive-expulsion, constant-pressure tankage selected primarily on the basis of the availability of flight-proven technology and hardware. Dry nitrogen was selected as the pressurant gas as the consequence of a trade study that identified nitrogen as having the lowest cost where small variations in weight and volume are not overriding considerations.

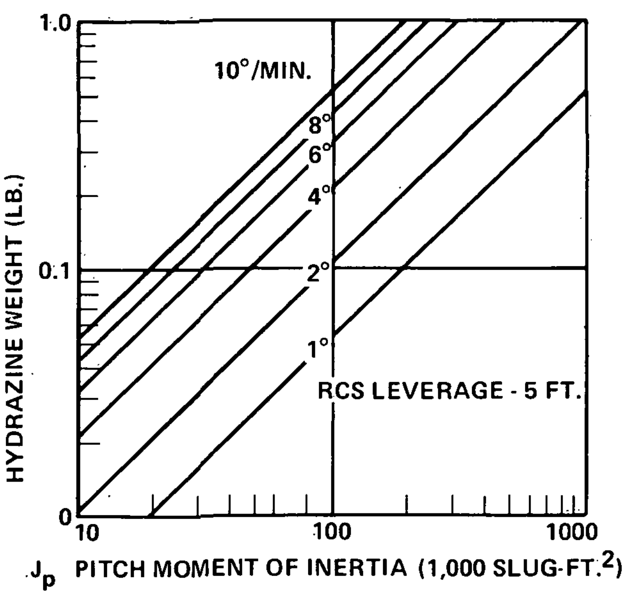


Figure 3-82. Fuel Weight versus Vehicle Size Per Maneuver

All free-flying RAMs use the flight-proven 25-lbf RCS thrusters developed for the Titan transtage. These appear in four clusters of six each for the shuttle-supported free-flying RAMs, which require only attitude control. Four additional clusters of two each are supplied on station-supported free-flying RAMs to provide six-axis control (rotation plus translation). The 600-lbf thrusters are currently being developed by Rocket Research Corporation.

Contamination considerations alone would probably preclude use of RCS for observational maneuvers; however, examination of the fuel weight per maneuver curves (Figure 3-82) illustrated another consideration. A 100,000 slug-ft^2 vehicle maneuvering five times per day at a nominal rate of 6 deg/min would consume 1.5 pounds of propellant per day (270 pounds between projected six-month shuttle visits). By contrast, the use of CMGs sized for maneuvering at that rate keeps a ten-year propellant requirement to less than 270 pounds and minimizes propulsion contamination from combustion products.

3.3.12 MASS PROPERTIES. The estimated mass properties of the basic shuttle-supported and station-supported free-flying RAMs are presented in Table 3-24. The weights shown in this table are based on the configuration designs and subsystem analyses found in Section 3.3.1 through 3.3.11.

Allowances for installation hardware and for other detail design features not fully delineated in the designs were included in the weight estimates. The weight breakdown format conforms to the requirements of MIL-M-38310A.

The basic free-flying RAM weights shown in Table 3-23 do not include the weight of structural and subsystem add-ons, experiments, residuals, reserves, and expendables.

3.3.13 FREE-FLYING RAM USER PROVISIONS. The basic free-flying RAM provides pressurizable volume and access to critical instruments that require frequent servicing or replacement of components. Table 3-24 shows net resources and accommodations available for payloads and experiments.

The basic free-flying RAM payload carrier is 22 feet long, accommodates mounting of payloads at one end through a pressure bulkhead, and contains 920 cubic feet of pressurizable volume for experiment equipment in addition to 510 cubic feet for subsystems and 580 cubic feet for crew access during on-orbit servicing.

Increased internal space is available by adding a barrel section (six or eight feet long). The total length of the free-flying RAM plus the external equipment should be less than 53 feet.

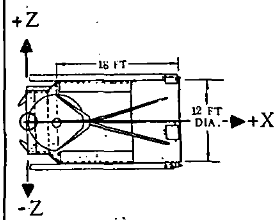
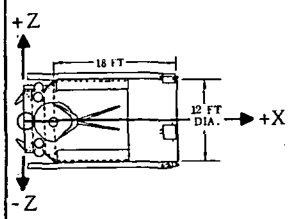
The net available power for experiment equipment is 1.3 kW. Additional power capability is available through addition of a solar array panel area as well as a peak-load battery and charger.

Basic data acquisition capability is 51 Gbits/orbit. Input data rates to bulk processing are adjustable up to a peak of 1.24 Gbps. Data can be transmitted from onboard storage or direct readout at rates up to 10 Mbps, or 10 MHz via TDRS.

The guidance and navigation subsystem provides reference position and velocity data as well as timing information. The module includes equipment for pointing to ±1 arc-sec accuracy and ±0.5 arc-sec stability and timing accuracy of ±0.1 second.

The basic thermal control capability can maintain cold-plate temperature between 80°F and 115°F at experiment heat loads up to 5000 Btu/hr. If lower temperatures, closer temperature control, or higher heat loads are to be accommodated, a fine thermal control and supplemental radiator area can be added as experiment integration equipment.

Table 3-23. Basic* Free-Flying RAM Mass Properties Summary

System (MIL-M-3810A)	 Shuttle Supported	 Space Station Supported
Structure	3259	3259
Induced Environmental Protection	1223	1276
Docking	238	238
Propulsion	462	569
Prime Power Source	1273	1254
Electrical Conversion and Distribution	312	312
Guidance and Control	998	1016
On-Board Checkout	18	18
Data Management	376	376
Communications	265	265
Displays and Controls	35	35
Electrical Wiring	396	396
Atmospheric Control	135	135
Thermal Control	557	557
Life Support	7	7
Interiors	220	220
Basic Weight (lb)	9774	9933
Center of Gravity Location (inches from datum on sketch of orbital configuration)		
X	111	107
Y	9.2	9.0
Z	5.3	5.3
Mass Moment of Inertia About CG (slug-ft^2)		
I_{XX}	7113	7298
I_{YY}	15620	15250
I_{ZZ}	15890	15520
Product of Inertia About CG (slug-ft^2)		
I_{XY}	-1030	-950
I_{YZ}	-380	-377
I_{XZ}	-203	-162

*Factory complete condition. Excludes subsystem add-ons, experiments, crew and crew equipment, residuals, reserves, and in-flight losses.

Table 3-24. Free-Flying RAM Support Capabilities

Parameter	Total Capability	Net Capability for Experiments	Explanatory Note
1. Volume (ft^3), pressurizable	2010	920	Four access ways 3.25 feet in diameter by 18 feet long (≃580 cu ft). Subsystems require about ≃510 cu ft.
2. Crew size/manhours per day	2/24	2/21.5	For servicing only.
3. Electrical Power			
Total, unregulated (±15%)	2.8 kW	1.3 kW	
28 vdc ±5%/115 vac, 400 Hz	1.0 kW/1.0 KVA	0.5 kW/0.5 kva	
4. Data Acquisition			Bulk processing in payload reduces peak rate to RAM to 1.59×10^8 bps from 1.24 Gbps
Max data rate	1.24 Gbps	1.24 Gbps	
Storage (b/reel/No. of reels)	$5.1 \times 10^{10}/1$	$5.1 \times 10^{10}/1$	
5. Control and Display	none	none	Console in sortie RAM
6. Communications Transmission capacity	TDRS: 10 Mbps digital, 10 MHz analog; Ground Network: 5 Mbps digital	TDRS: 10 Mbps digital, 10 MHz analog; Ground Network: 5 Mbps digital	
7. Guidance, Navigation & Control			
Pointing accuracy (arc-sec)/stability (arc-sec/observation)	±1/±0.5	±1/±0.5	With CMGs
Position (n. mi.)/velocity (fps)	±1/TBD	±1/TBD	
8. Thermal Control			May need additional radiator area for fine thermal control.
Air temp/heat rejection	10,500 Btu/hr, total	—	
Cold plate temp/heat rejection	—	80 to 115°F/0 to 5000 Btu/hr	
9. Viewports	None	None	
10. Feedthroughs		Adapted to experiment	As necessary in experiment integration bulkhead.

3.4 RAM SYSTEM INTERFACES

The RAM mission requires that RAM elements interface with other programs including the space shuttle, space station, communication network, and the ground system as shown in Figure 3-83. These interfaces are of importance to RAM payload carrier design, since RAM system must be compatible with the interfacing systems and is dependent on the support received from these systems. Another category of interfaces is the interface connections between the RAM elements. In the sortie mission mode, greater experiment capability can be obtained by combining pressurized RAMs or pressurized RAMs to unpressurized RAM and, in the case of free-flying mission servicing, a sortie RAM to the free-flying RAM. In each case, the pressurized RAM (sortie RAM or RSM) provides the resources to the other RAM element.

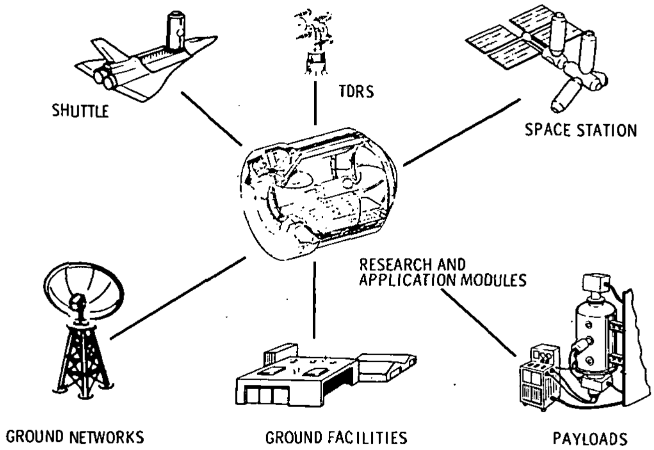


Figure 3-83. RAM System Interfaces

3.4.1 INTERSYSTEM INTERFACES.

Major interfaces between the RAM project and other systems for shuttle-supported and space station-supported mission modes are tabulated in Tables 3-25 and 3-26. During the development of RAM payload carrier design concepts, each concept was assessed for design and operational compatibility with the intersystem interface requirements and to ensure that RAM project payload carriers and associated systems and subsystems were fulfilling these requirements in a logical and cost-effective manner. To meet these objectives, trade studies and analyses were performed to define subsystems and their interfaces that were insensitive to changes in interfacing systems, were economical, had little or no impact on the interfacing system design and operational requirements, and were flexible to changing RAM payload carrier requirements. Based on these studies and analyses, the RAM payload carrier interface with other systems (including space shuttle, space station, communication network, and ground system) was minimized as much as practicable within the constraints specified by the RAM project guidelines. In taking this approach, the RAM payload carrier interfaces were simplified and minimized the impact of the RAM project on the interfacing systems.

3.4.1.1 Shuttle Interfaces. RAM payload carriers to be used in the sortie mission mode, including the sortie RAM and RSM, were designed to be essentially self-sufficient, thereby having minimum interface with the shuttle system. This is consistent with the preceding goals and the shuttle's requirement for minimum shuttle refurbishment costs and recycle time. Figure 3-84 presents the typical RAM payload

Table 3-25. Reference Space Shuttle Interfaces

Characteristic	Interface	Source/Rationale
Cargo Bay Size	15-ft diameter/60 ft length*	Shuttle — payload ICD
Payload Deployment	Hinged or manipulator	Minimize RAM sensitivity
Entry CG Control (ABES out) 20,000 lb payload	12-59 ft aft of interface	Shuttle — payload ICD (ABES~on CG)
32,000 lb payload	17-48 ft aft of interface	
Electrical Average/Peak/Energy	1000 W/3000 W/50 kW-hr	Shuttle — payload ICD
Voice & Command Communication	VHF/TDRS; 10 Kbps (substituted for voice links)	Shuttle — payload ICD
Data Transmission	S-band/ground network system; 1 Mbps	Shuttle — payload ICD
Crew Provisions	28 man days consumables	Shuttle — payload ICD
Passenger Habitability	Non-compartmentalized	Shuttle phase B design
Pointing Accuracy	± 0.5 deg	Shuttle — payload ICD
Performance to Orbit	80% capability to orbit, ABES out	Shuttle — payload ICD (level 1 requirement)
Landing Weight	40,000 lb; ABES out	Shuttle — payload ICD
Crew Complement	2 orbiter crew plus 2 payload crew	Shuttle — payload ICD
Mission Duration	7 days (nominal)	Level 1 guidelines
Contamination Sources	Attitude control engines, cabin leakage, outgassing	Shuttle phase B design

*Maximum RAM payload size limit 14-ft diameter/58 ft length, per Level 1 guidelines.

Table 3-26. Reference Space Station Interfaces

Characteristic	Interface	Source/Rationale
Docking Port Locations & Number Available	Nadir & 60 deg from zenith ISS:* 4 GSS:** 8	MDAC modular space station Jul/Aug 1971
Electrical-Average/Peak (1 hr)	ISS: 4.8/7.2 kW available GSS: 12.1/18.1 kW available	
Tracking & Control of Free-Flying RAM	ISS: available GSS: available	Assumed required capability
Thermal Control	Station dissipates metabolic heat	Air exchange only assumed
Environmental Control	Station provides EC/LS	MDAC modular space station Jul/Aug 1971
Orbit	240 to 270 n. mi./55 deg inclination	
Crew Size	ISS: 4.6 GSS: 9.5 } for experiment operations	
EVA	2 airlocks	
Pointing Accuracy	± 0.25 deg	
Contamination Sources	ACPS, leakage, outgassing	

*ISS — Initial Space Station
**GSS — Growth Space Station

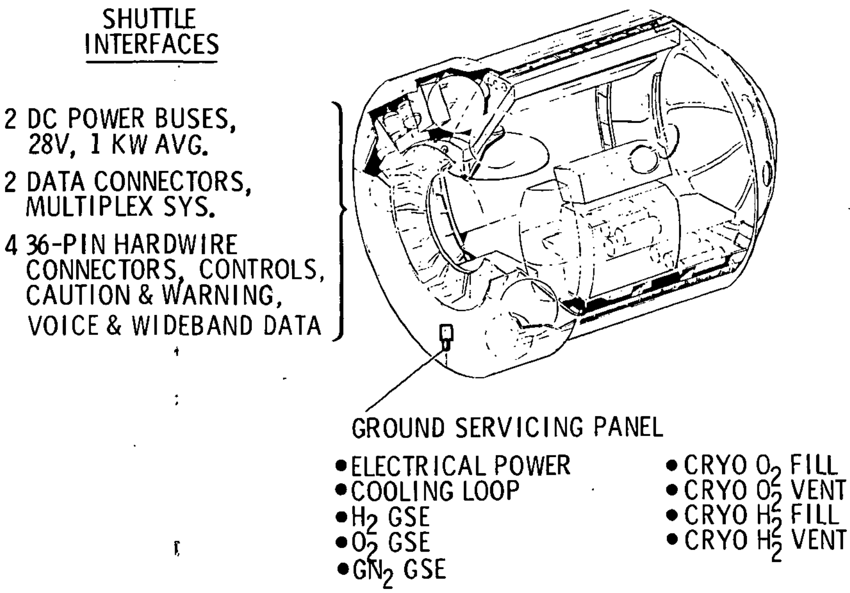


Figure 3-84. Typical RAM Payload Carrier Interfaces

carrier functional interface with the shuttle and ground servicing connections. The shuttle electrical power serves as a backup source to RAM payload carrier electrical power subsystem while on-orbit. Redundant power buses are provided by shuttle. Two data connectors tie into the shuttle communication subsystem, which is shared by RAM system with the shuttle for data transmission and receiving of commands from the communication ground network system. A caution and warning interface is provided to satisfy the shuttle requirement for safety monitoring of the payload subsystems by the orbiter crew. The ground servicing panel is the interface connection for providing resources while the RAM payload carrier is mated to the shuttle orbiter vehicle at the launch pad and after postlanding in the orbiter safing area.

Other orbiter capabilities used by the RAM payload carrier include:

a. Habitability for RAM payload crew of up to two and crew provisions for 14 man days.

b. Food and hygiene facilities for RAM payload crew.

c. Orbit altitude up to 450 nmi for inclinations of 28.5 degrees to sun synchronous (about 97 degrees).

d. Pointing and stabilization.

e. Mission specialist console for monitoring and control of payload carriers.

3.4.1.2 Space Station Interfaces. While the RAM payload carriers are basically self-sufficient in the sortie mode, they are almost completely dependent on the space station for support functions in the station-attached mode because the space station design includes consideration for having RAM payload carriers operating attached to the station. The space station provides the RAM payload module with the following support functions: environmental control and life support, data acquisition and storage, caution and warning, communication, guidance, navigation and control, electrical

power, and rendezvous and docking control of free-flying RAMs. Thermal subsystem support is not provided by the station except for metabolic heat dissipation through air exchange. Use of the station-provided EVA airlocks is required for experiments such as life sciences, where extravehicular access is the basic requirement and experiment-peculiar airlock modifications are not anticipated. Peaking batteries are provided by the RAM payload modules whenever the expected electrical power demands exceed the station power allocation. The space station also provides tracking of free-flying RAMs that operate in the station-supported mode.

3.4.1.3 Communication Interfaces. In the sortie and station-attached mission modes, the RAM payload carrier is dependent on the shuttle and the space station, respectively, for communication links to the ground stations. The shuttle orbiter vehicle incorporates within its communication subsystem both VHF/Tracking and Data Relay Satellite (TDRS) and S-band/ground network system RF communication links, and the space station RF link to ground station is TDRS, Ku-band and VHF. Characteristics of the TDRS and the ground network system are presented in Table 3-27.

Table 3-27. Reference Communications/Data System Interfaces

SYSTEM	CHARACTERISTIC	INTERFACE	SOURCE
GROUND NETWORK	LOCATION OF STATIONS	MADRID, CANBERRA, ROSMAN, FAIRBANKS, GOLDSTONE	MODEL FOR GROUND NETWORK & SYNCHRONOUS SATELLITE COMMUNICATION SYSTEM
	COMMAND DATA	200 BPS	
	TRACKING	UNIFIED S-BAND	
	DIGITAL DATA RATE	1 MBPS	
	VIDEO BANDWIDTH	1.5 & 3.5 MHz	
	GROUND DATA RATE	72 K BPS (EA. STA.)	
TRACKING & DATA RELAY SATELLITE (TDRS)	NO. OF SATELLITES	2 + 1 ON-ORBIT SPARE	
	LOCATION OF SATELLITES	15° W / 145° W	
	TRANSMISSION FREQUENCY	VHF (VOICE & COMM.)	
	Ku-BAND DATA	50 MBPS (OR ANALOG EQUIV.)	
	VHF DATA	10 KBPS	

Free-flying RAMs require the payload carriers to provide their own RF communication subsystem. These are different for the shuttle-supported and the space-station-supported free-flying RAMs. In the shuttle-supported RAM payload carriers, two RF links are provided: one to communicate with the ground station through TDRS,

using both Ku-band and VHF, and the other for the shuttle to communicate with the free-flying RAM on a servicing mission for rendezvous and docking using S-band and VHF frequencies. For the free-flying RAM supported by the space station, the communication interface between the payload carrier and the space station is by Ku-band telemetry, tracking, and command. The space station relays the data to the ground station through TDRS.

3.4.1.4 Ground Interfaces. RAM payload carrier interfaces with the shuttle orbiter vehicle are connected during the prelaunch ground operations when the payload carrier is mated to the orbiter. From then on, the RAM vehicle is supported by the ground system through the remainder of the prelaunch operations and the launch operations. It is further supported by ground system after the orbiter returns to the launch site with the RAM payload carrier and both the orbiter vehicle and its payload are safed during the postlanding safing operations.

Installation of the RAM payload carrier into the orbiter vehicle cargo bay is planned to be initiated at T-6 or -7 days prior to launch and can be accomplished in a single shift. Immediately after installation of the payload carrier into the cargo bay with structural attachment points secured and shuttle-to-payload-carrier interface connections completed, verification of the installation will be accomplished to ensure proper mating of the two vehicles. During this period, the ground system will provide the necessary resources, including electrical power, environmental control, thermal control, and communication, to accomplish the mating and verification functions. After transfer of the shuttle to the launch pad, the ground system interfaces with the RAM payload carrier through the payload umbilicals provided through the payload swing arm of the launch pad service tower. These umbilicals provide the service lines that connect to the RAM payload carrier's ground servicing panel through the orbiter payload service panel. Services provided by the ground system at the launch pad include electrical power, cooling loop, cryogenic fluids, and gaseous fluids. These same service lines are provided at the postlanding safing area, where safing operations (e.g. draining and purging cryogenic tanks) are performed.

3.4.2 INTRASYSTEM INTERFACES. Interface requirements were defined for the elements of the RAM project. Representative payload support requirements that formed the basis for the RAM payload carrier designs were defined, including their physical and mission requirements, supporting resources, flight operations, and ground operations. These payload requirements are documented in Appendix A of Volume 1, RAM Technical Data Document, GDCA-DDA71-003.

Within the family of three basic elements of RAM payload carriers (pressurized, unpressurized, and free-flying), various combinations of payload carriers have been configured to support diverse technological and scientific investigations and practical applications in earth orbit. When two or more RAM payload carriers are mated to support payloads, one of the payload carriers is a pressurized RAM that supplies the basic resources to conduct experiments in the others. Figure 3-85

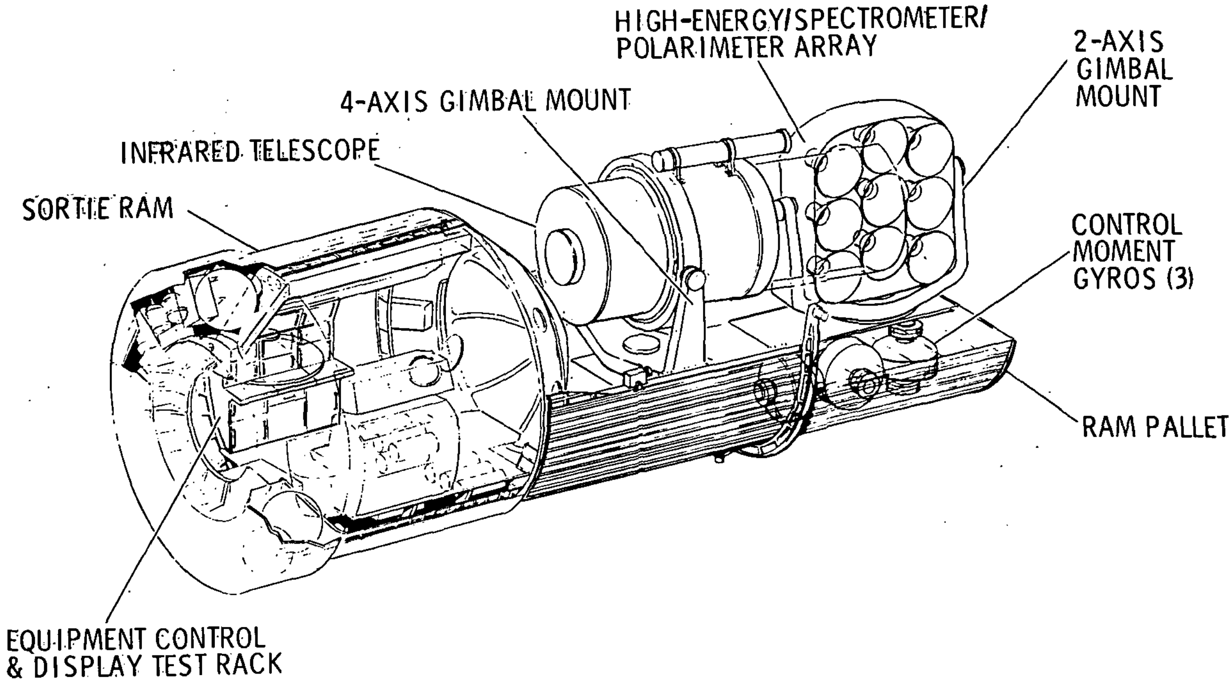


Figure 3-85. Sortie Mission Payload

illustrates a representative sortie astronomy mission payload using a sortie RAM and RAM pallet. The astronomy payloads and payload integration equipment mounted on the RAM pallet receive their functional support from the sortie RAM. These interfaces for electrical power, data management, communication, and thermal control are presented in Figure 3-86 and represent the standard interface between sortie RAM (and RAM payload module) and the RAM pallet.

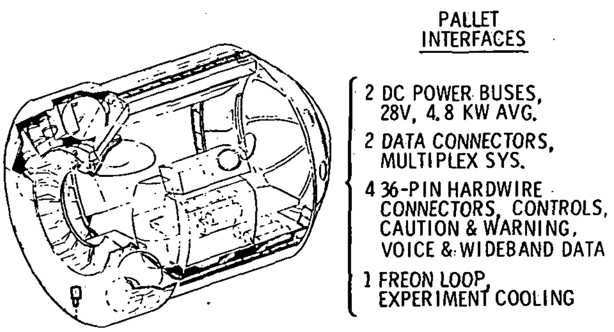


Figure 3-86. Sortie RAM to RAM Pallet Interfaces

RAM payload modules employed in the sortie mission mode are always combined with either an RSM or sortie RAM, either one supplying the resources and services to conduct experiments in the RAM payload module. Figure 3-87 illustrates a representative sortie mission RAM payload module housing a physics payload. Interface between the RAM payload module and the RSM or sortie RAM is presented in Figure 3-88. As shown, there is a relatively large number of interface functions between the two payload carriers.

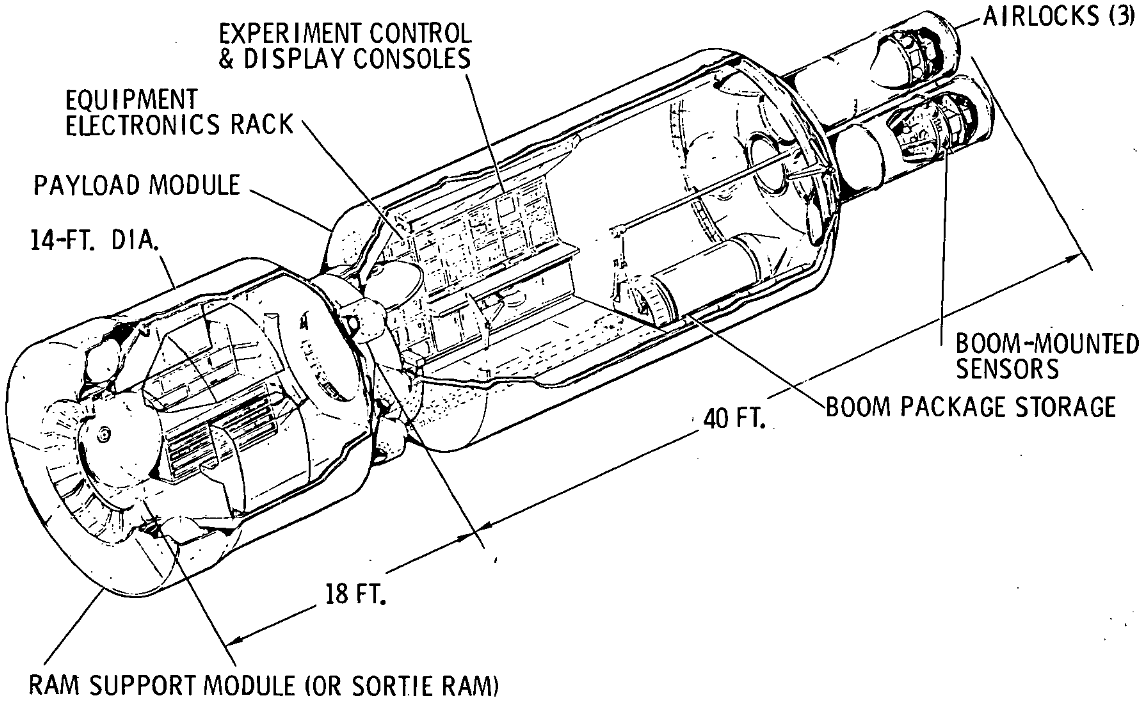


Figure 3-87. RAM Payload Module Sortie Mission

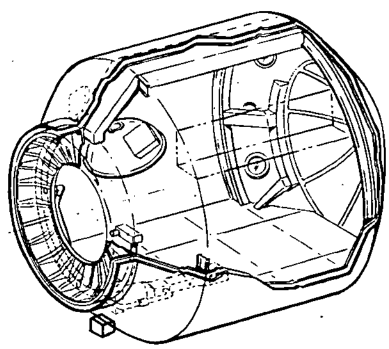


Figure 3-88. Sortie RAM Payload Module Interfaces

Since a RAM pallet can be mounted to the RAM payload module end opposite to the RSM or sortie RAM interface, RAM pallet interfaces identical to the interfaces specified in Figure 3-86 are also required to mount astronomy or other payloads for sortie missions. All resources to the RAM pallet such as power and cooling are provided from the RSM or sortie RAM and all data goes to it. Control functions are initiated within the pressurized volume, and caution and warning signals are displayed on the control console therein.

In the previous section, it was stated that shuttle-supported free-flying RAMs are serviced by a sortie RAM attached to orbiter vehicle. To use the sortie RAM as a free-flying RAM servicer, the domed bulkhead is replaced by a 102-inch-diameter preassembled docking hatch assembly, as shown in Figure 3-89. The sortie RAM provides oxygen and nitrogen to repressurize the free-flying RAM, which is unmanned and unpressurized during orbital operations. An air duct, together with portable fans, provides air distribution. Test and checkout operations are conducted from the display and control console in the sortie RAM. These interfaces between the sortie RAM and the free-flying RAM are shown in Figure 3-90.

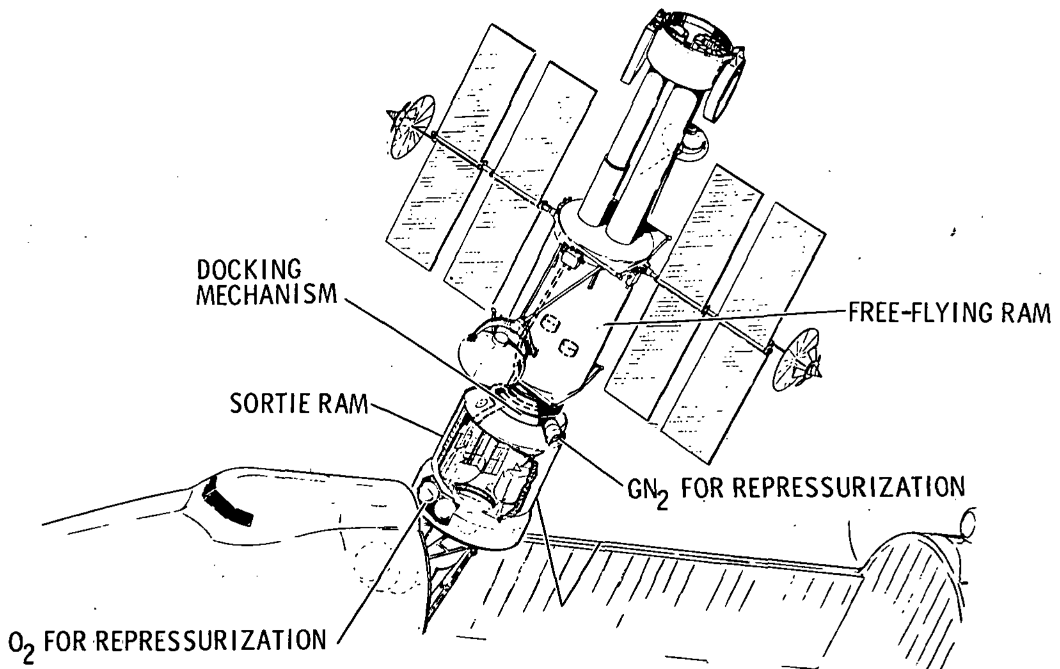


Figure 3-89. Servicing of Free-Flying RAM

A summary of the intersystem and intrasystem interface connections for each RAM element developed in the RAM Phase B Study is presented in Table 3-28. These connections are not all used at any one time, but must be provided to ensure compatibility of each payload carrier to all of its interfacing elements, depending on the selected operating mission mode and the mission objective. Another summary of the interfaces

FREE-FLYING RAM - SHUTTLE SUPPORTED	
2	DC POWER BUSES, 28V, 4.8 KW AVG.
2	DATA CONNECTORS, MULTIPLEX SYSTEM
4	36-PIN HARDWIRE CONNECTORS, CONTROLS/ CAUTION & WARNING
1	ATMOSPHERE SUPPLY
2	REPRESSURIZATION LINES, O_2 & N_2
1	AIR PUMPDOWN PIPE

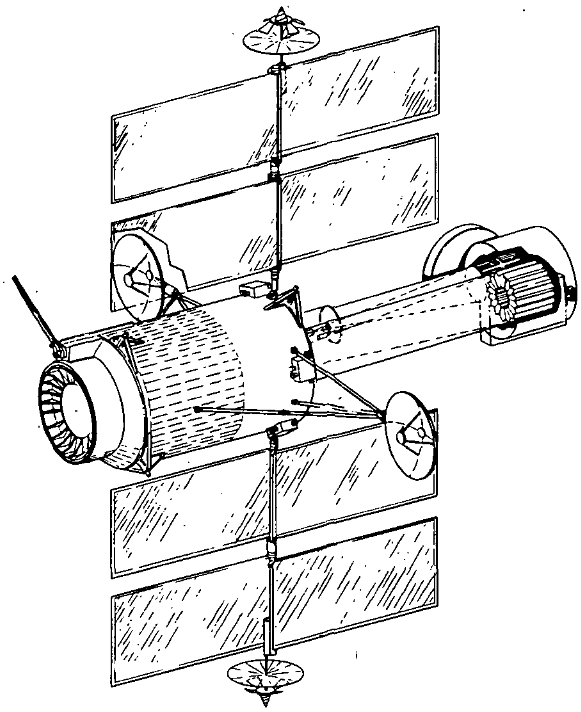


Figure 3-90. Free-Flying RAM Interfaces

listing the connections installed at each end of RAM elements and the mating interfaces on the orbiter vehicle and space station is presented in Table 3-29. The interface requirements presented define the functions required for the RAM payload carriers to perform their mission.

Table 3-28. Interface Connection Requirements

Connection	Free-Flying RAM to			RAM Payload Module (Fwd) to			Sortie RAM (Fwd) to Shuttle	RSM (Fwd) to Shuttle	RAM Payload Module (Aft) to Palletized RAM	Sortie RAM (Aft) to Palletized RAM
	Station	RAM (Aft)	Shuttle	Station	Shuttle	RSM (Aft)				
Potable Water Line	-	-	-	X	-	X	-	-	-	-
Control Circuit	X	X	X	X	X	X	X	X	X*	X*
Dc Power Bus	X	X	X	X	X	X	X	X	X*	X*
Water Cooling Loop	-	-	-	-	-	X	-	-	-	-
Propellant Line*	X	-	-	-	-	-	-	-	-	-
Freon Line*	-	-	-	-	-	X	-	-	X*	X*
Oxygen Repressurization Line	X	X	-	X	-	X	-	-	-	-
High-Pressure Gas Line*	X	-	-	-	-	-	-	-	-	-
Water Cooling Loop	-	-	-	-	-	X	-	-	-	-
Ac Power Bus	-	-	-	X	-	-	-	-	-	-
Data Connector	X	X	X	X	-	X	X	X	X*	X*
Control Circuit	X	X	X	X	X	X	X	X	X*	X*
Return Air Pipe	X	X	-	X	-	X	-	-	-	-
Air Pump Down-Pipe	X	X	X	X	-	X	-	-	-	-
Control Circuit	X	X	X	X	X	X	X	X	X*	X*
Data Connector	X	X	X	X	-	X	X	X	X*	X*
Dc Power Bus	-	-	-	-	-	X	-	-	-	-
Ac Power Bus	-	-	-	X	-	-	-	-	-	-
Water Cooling Loop	-	-	-	-	-	X	-	-	-	-
High-Pressure Gas Line	X	-	-	-	-	-	-	-	-	-
Nitrogen Repressurization Line	X	X	X	X	-	X	-	-	-	-
Freon Line*	-	-	-	-	-	X	-	-	X*	X*
Propellant Line*	X	-	-	-	-	-	-	-	-	-
Water Cooling Loop	-	-	-	-	-	X	-	-	-	-
Dc Power Bus	X	X	X	X	X	X	X	X	X*	X*
Control Circuit	X	X	X	X	X	X	X	X	X*	X*
Potable Water Line	-	-	-	X	-	X	-	-	-	-
Conditioned Air Pipe	X	X	-	X	-	X	-	-	-	-
Ground Servicing Panel*	-	-	X	-	X	-	X	X	-	-
Docking Target/Telescope*	X	X	X	-	-	-	-	-	-	-

* Outside Pressurized Volume

Table 3-29. Element Interface Requirements Summation

Connection	Station	Shuttle	Free-Flying RAM (Fwd)	RAM Payload Module (Fwd)	RSM (Fwd)	RSM (Aft)	Sortie RAM (Fwd)	Sortie RAM (Aft)	Palletized RAM (Fwd)
Potable Water Line	X	-	-	X	-	X	-	-	-
Control Circuit	X	X	X	X	X	X	X	X**	X*
Dc Power Bus	X	X	X	X	X	X	X	X**	X*
Water Cooling Loop	-	-	-	X		X	-	-	-
Propellant Line*	X	-	X	-	-	-	-		-
Freon Line*	-	-	-	X	-	X	-	X**	X*
Oxygen Repressurization Line	X	-	X	X	-	X	-	X	-
High-Pressurization Gas Line*	X	-	X	-	-	-	-		-
Water Cooling Loop	-	-	-	X	-	X	-	-	-
Ac Power Bus	X	-	-	X	-	-	-	-	-
Data Connector	X	X	X	X	X	X	X	X**	X*
Control Circuit	X	X	X	X	X	X	X	X**	X*
Return Air Pipe	X	-	X	X	-	X	-	X	-
Air Pump Down-Pipe	X	-	X	X	-	X	-	X	-
Control Circuit	X	X	X	X	X	X	X	X**	X*
Data Connector	X	X	X	X	X	X	X	X**	X*
Dc Power Bus	-	-	-	X	-	X	-	-	-
Ac Power Bus	X	-	-	X	-	-	-	-	-
Water Cooling Loop	-	-	-	X	-	X	-	-	-
High-Pressurization Gas Line*	X	-	X	-	-	-	-	X	-
Nitrogen Repressurization Line	X	X	X	X	-	X	-	X	-
Freon Line*	-	-	-	X	-	X	-	X**	X*
Propellant Line*	X	-	X	-	-	-	-		-
Water Cooling Loop	-	-	-	X		X	-	-	-
Dc Power Bus	X	X	X	X	X	X	X	X**	X*
Control Circuit	X	X	X	X	X	X	X	X**	X*
Potable Water Line	X	-	-	X	-	X	-	-	-
Conditioned Air Pipe	X	-	X	X	-	X	-	X	-
Ground Servicing Panel*	-	X	X	X	X	-	X	-	-
Docking Target/Telescope*	X	X	X	-	-	-	-	X	-

* Outside pressurized volume.

** Connections provided outside 102-inch diameter for palletized RAM when docking interface removed.

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 4

MISSION ANALYSIS

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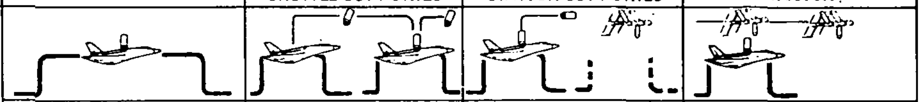
SECTION 4

MISSION ANALYSIS

Mission requirements of the sortie, free-flying, and station-attached RAM mission modes are presented in this section. The requirements for the RAM elements are derived from the flight mission requirements, ground and flight operations, crew requirements, and shuttle and space station capabilities.

RAM mission requirements are derived from RAM payload operational requirements. Table 4-1 summarizes the primary RAM mission requirements for each mission mode.

Table 4-1. Summary of Primary RAM Mission Requirements

ITEM	SORTIE MISSION	FREE FLYING MISSION: SHUTTLE SUPPORTED	FREE FLYING MISSION: STATION SUPPORTED	STATION-ATTACHED MISSION
				
ORBIT ALT. – N.MI.	100 - 400	300 - 400	240 - 270	240 - 270
ORBIT INCL. - DEG.	28.5 - 97	28.5 - 55	55	55
ORBIT MAINTENANCE	BY SHUTTLE <120 N.MI.	BY SHUTTLE <~350 N. MI.	INTERMITTENT - BY RAM	INTERMITTENT - BY STATION
ORIENTATION	VARIOUS – BY SHUTTLE	INERTIAL – BY RAM	INERTIAL – BY RAM	VARIOUS – BY STATION
RENDEZVOUS & DOCKING	——	ATTITUDE CONTROL	ATTITUDE AND ΔV CONTROL	BY SHUTTLE
PAYLOAD RESOURCES	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER GENERATION DATA HANDLING HEAT REJECTION	POWER DISTRIBUTION DATA HANDLING HEAT REJECTION
COMMUNICATIONS	TDRS/GROUND NETWORK SYSTEM	TDRS - SERVICE MISSION	STATION	STATION
SERVICING	GROUND	SERVICE MISSION	STATION	STATION
PAYLOAD CREW	2 TO 6	UNMANNED	UNMANNED	2 TO 6
SERVICE CREW	——	2 (MINIMUM)	2 (MINIMUM)	2 (MINIMUM)

Orbit characteristics reflect payload requirements and shuttle capability, consistent with the current Interface Requirements Document (RAM Technical Data Document, GDCA-DDA72-006, Appendix B). In general, orbit maintenance is required by the shuttle for sortie RAM missions below 120 n. mi. altitude and for free-flying RAM missions below about 350 n. mi.

Orientation requirements vary by mission mode. Active rendezvous and docking capability by RAM payload carriers is required only in the station-supported, free-flying mode. Power generation, data handling, and heat rejection capability are

required in all mission modes. For shuttle-supported free-flying RAM missions, the free-flying RAM-to-ground communications link is direct TDRS. In the station-supported free-flying RAM missions, the communication link is to the station, which links to the ground via the TDRS. On-orbit servicing is required in the free-flying and station-attached mission modes and ground servicing is performed for the sortie mission mode.

4.1 SORTIE MISSIONS

4.1.1 MISSION OPERATIONS. As shown in Figure 4-1, major operations phases in a sortie mission turnaround cycle are: prelaunch and launch, boost to orbit and RAM payload carrier/payload preparation, on-orbit experimentation, RAM payload carrier/payload securing for return, RAM payload carrier/payload maintenance and refurbishment, and payload integration. The prelaunch phase starts when payload integration is complete and a launch date has been set. Operations accomplished during this phase include RAM weight and balance tests, loading of non-time-critical expendables, verification of RAM payload carrier/payload readiness for installation into the orbiter, installation of RAM payload carrier/payload in the orbiter, checkout of the RAM payload carrier/orbiter interface, and orbiter/booster mate.

Launch operations begin with transportation of the shuttle to the launch pad, followed by installation of launch pad payload interface connections, verification of shuttle/RAM payload carrier readiness for liftoff, loading of time-critical expendables, and shuttle liftoff.

During boost and ascent to orbit, RAM payload carrier provides environmental protection and subsystem resources to the payload. After reaching orbit, RAM element is deployed from the orbiter cargo bay, if required. (Deployment may be necessary for payloads with exacting field of view requirements and/or thermal control, but many payloads can operate while in the orbiter cargo bay.) When deployment is necessary, RAM payload carrier is either docked to the orbiter topside docking port, if deployment is by orbiter manipulators, or remains attached to the cargo bay airlock hatch through a flexible pressure tunnel, if deployed using a deployment mechanism.

RAM payload carrier subsystems and payload operations are then checked out in preparation for the on-orbit experiment period. Experiments are conducted over about a six-day period. During this phase, the shuttle is required to: 1) drift for extended periods to minimize acceleration levels when zero-g laboratory experiments are being conducted, 2) hold specific attitudes with a ±0.5 degree accuracy for earth observation measurements lasting up to 30 minutes per opportunity during repeated passes over the target area, and 3) hand over attitude control to the RAM payload carrier control-moment gyros (CMGs) for extended periods (days) when extremely high pointing accuracy and stability and a minimum contamination environment are necessary (during celestial observation experiments).

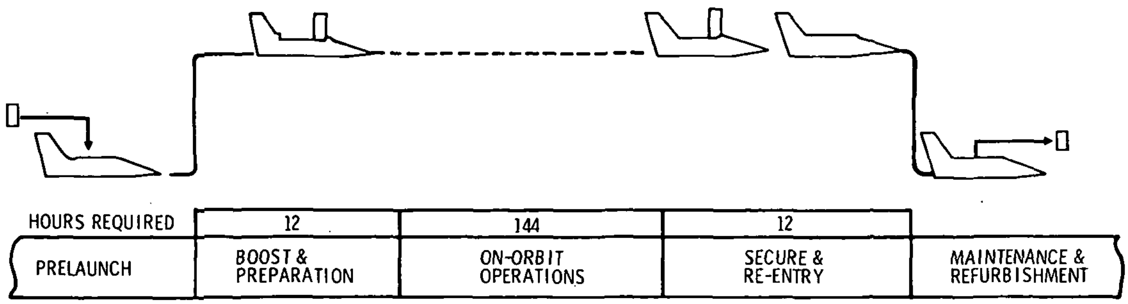


Figure 4-1. Sortie Mission Operations

Crew operations consist of setup, calibration, conduct, and analysis of scientific and applications experiments in the Astronomy, Physics, Earth Observations, Communication/Navigation, Materials Science, Technology, and Life Sciences disciplines. Sortie missions are particularly attractive for early-program, precursor experiments and provide the capability for attaining the higher inclination orbits (up to polar and sun-synchronous) preferred for some earth observation and magnetosphere measurement payloads.

At the conclusion of the experimentation period, the payload and RAM payload carrier are prepared by the crew for return to earth. After landing, the orbiter is safed and time-critical data is removed from RAM element and delivered to the user. The RAM payload carrier and its payload is then removed from the orbiter and delivered to the maintenance/refurbishment facility.

The RAM payload carrier and its payload are repaired and maintained, as required, if the same (or slightly modified) payload is to be reflown in the near future. Sortie missions provide the capability for rapid turnaround and reflight of the same payload housed in a sortie RAM or a RAM payload module, and for rapid turnaround of RSM subsystems in support of multiple RAM payload modules. After repair and maintenance, the RAM payload carrier is available for flight crew training or is placed in storage before delivery to the prelaunch facility in final preparation for the next flight. When a new payload is to be installed in the sortie RAM or RAM payload module, the old payload is removed and the RAM payload carrier is prepared for the new payload.

The refurbished RAM payload carrier is delivered to the payload integration facility where the new payload is installed, calibrated/aligned, and RAM payload carrier/payload compatibility verified. After payload verification, the RAM payload carrier/payload is available for flight crew familiarization and procedures training. The RAM payload carrier/payload is ready for prelaunch operations at the completion of the flight crew training.

4.1.2 CRITICAL OPERATIONS. Experiment operations are conducted while the RAM element is attached to the shuttle. Guidance and navigation is provided by the shuttle. Pointing accuracy and stability control exceeding the capability of the shuttle is supplied by the RAM payload carrier. Limited resources (power, communication/ data facilities) are available from the shuttle; additional resources, as required, are provided by the RAM payload carrier. Contamination of the immediate vicinity of the shuttle is reduced by programming all venting. Contamination countermeasures such as lens covers are supplied by the RAM element. Habitability for a payload crew of two is provided in the orbiter; provisions for payload crews larger than two is provided by RSM. RAM sortie mission payload requirements for orbit altitudes from 100 to 300 n.mi. at inclinations of from 28.5 to 97 degrees are within shuttle capability. Critical operational requirements are presented in Table 4-2, along with sortie mission characteristics that are important to the user.

Quick RAM payload carrier turnaround requires adequate mounting and access space plus standard interfaces. Use of the sortie RAM or RAM payload module as a non-dedicated sortie laboratory dictates adequate resource provision and standard interfaces to service a variety of experiment equipment. Provisions for external attachment are required for mounting RAM payload carrier/payload equipment. RAM element operation in or out of the cargo bay requires that the thermal system operate either in or out of the bay. Post-landing servicing requires ground cooling and power supplied by GSE.

4.1.3 EXPERIMENT FLIGHT OPERATIONS REQUIREMENTS. Major experiment requirements for on-orbit operations are discussed in the following paragraphs.

a. Orientation. The three basic sortie payload orientation modes are shown in Figure 4-2. For the zero-g laboratory, use of the shuttle attitude control propulsion subsystem (ACPS) is sometimes acceptable when the RAM payload carrier is not deployed. Because of the thermal control subsystem design, however, the payload carrier cannot always be operated in the undeployed configuration for more than a short while. In these cases, the shuttle must drift to minimize acceleration levels for the zero-g laboratory. Steady-state drag acceleration at 100 n.mi. altitude is approximately 10^{-5} g and transient accelerations resulting from crew and machinery motions are about 10^{-4} g in this mode. For Life Sciences payloads, special shuttle operating sequences (ACPS firing, venting, equipment operation) are required to meet the acceleration constraint of less than 10^{-5} g 95 percent of the time.

   The drift mode is not acceptable for earth measurements orientation because the large drift angles are incompatible with the duration and accuracy of the pointing requirement. ACPS stabilization is required during the actual measurement period. Operational and design contamination countermeasures are required.

Table 4-2. Critical Sortie Mission Operations Requirements

Function/Operation	Applicable RAM Element: Sortie RAM	RSM	RAM Payload Module	Palletized RAM	RAM Design Requirement	Shuttle Support or Constraint
Orientation	X	X	X	X	Inertial/Earth/Drift	-
Guidance & Navigation					Shuttle Supplied	± 0.5 n. mi.
Pointing - Accuracy				X	1 arc-sec	± 0.5 deg
- Stability				X	0.5 arc-sec/Observation	± 0.03 deg/sec
Resources	X	X			RAM Element Supplied (Beyond Shuttle Capability)	Limited Amounts
Contamination Control	X	X	X	X	Countermeasures	Operations Restrictions
Crew Habitability		X			3rd, 4th, 5th, & 6th Payload Crewmen	2 Payload Crewmen
Orbit					100 to 400 n. mi., 28.5 to 97 deg	Continental U.S. Launch
Quick Turnaround	X	X	X	X	Mounting, Access, Standard Interfaces	Vert/Horiz Access, Easy Mate, Standard Interfaces
Non-Dedicated Sortie Lab	X				Resources, Standard Interfaces	-
Unpressurized Experiment Mounting	X			X	Bulkhead, RAM Pallet Mount	Attachments
Operable In/Out Bay	X	X	X	X	Thermal Control Subsystem	Deployment Mechanism
Postlanding Servicing	X	X	X	X	GSE	Ground Cooling, Power

Celestial observation for long terms with high accuracy and minimum contamination eliminate both the drift mode and ACPS stabilization. Control moment gyros (CMGs) and gimbals in the RAM payload carrier are used in lieu of the shuttle ACPS for attitude control.

b. Contamination. The principal identified sources of contamination from the shuttle are 1) the ACPS exhaust, which is emitted mostly in a 90-degree cone about the thruster axis, 2) cabin leakage, which emerges from seams, hatches, and windows, 3) outgassing of nonmetallic materials such as paints, plastics, and resins continuously radiating in all directions, and 4) particulate matter that might dislodge from the cargo bay.

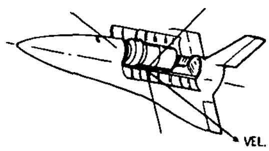
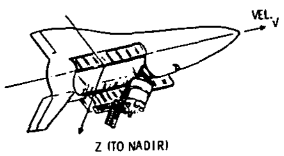
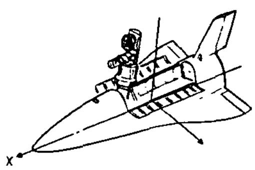
EXPERIMENT TYPE	ORBITER STABILIZATION	OTHER CONSTRAINTS
 ZERO-g LAB	ANY ORIENTATION ACCELERATION $<10^{-4}$g (LIFE SCIENCES $<10^{-5}$g 95% OF TIME)	INSENSITIVE TO ATMOSPHERE CONTAMINATION MINIMUM RADIATION
 EARTH MEASUREMENTS	Z TO NADIR POINTING ±0.5° (FOR PHYSICS ±5.0° CONTINUOUS) DATA TAKING 30 MIN./ORBIT	VIEWING ±60° FROM NADIR TARGET LIGHTING CONTAMINATION COUNTERMEASURES
 CELESTIAL OBSERVATIONS	X-POP POINTING ±0.5° FOR 0.1 - 5 HR. (NONPROPULSIVE STABILITY BY RAM PAYLOAD CARRIER)	VIEWING: $>45°$ - 90° FROM SUN $>30°$ - 60° FROM EARTH $>15°$ - 25° FROM HORIZON RADIATION $<10^{-3}$ RAD/HR. CONTAMINATION COUNTERMEAS.

Figure 4-2. Sortie Mission RAM Orientation Modes

Operational and design contamination countermeasures that reduce harmful effects of surface deposition, as well as scattering and absorption of radiation by contamination clouds, are to:

1. Restrict use of shuttle thrusters directed toward the payload wherever possible.

2. Use retractable covers or extendable sunshades and baffles to protect sensitive surfaces from impingement of contamination flux and solar UV radiation.

3. Precure all nonmetallic materials in a thermal vacuum environment.

4. Use nonpropulsive stability devices for payloads that require minimum contamination for long-duration, precision-pointing observations.

c. RAM Crew. RAM crew sizes for sortie missions vary from two to six mission/payload specialists. The initial crew complement will be two, increasing as payloads become more advanced. The early-capability crew size is for sortie mission payloads where the payload is housed in a sortie RAM and operates on a single-shift (one-shift-on and one-shift-off basis). Basic crew size is 2 + 2

(two orbiter crewmen and two payload crewmen, all housed in the orbiter). The minimum multiple-shift capability crew size is the smallest crew that can effectively utilize the experiment facility. This crew size does not use the entire facility capability in all cases, but represents a useful crew size that can produce meaningful scientific results in payloads of an advanced nature. The preferred multiple-shift crew size can make full use facility capabilities. The range of crew requirements for each experiment discipline is shown in Table 4-3.

Table 4-3. RAM Crew Sizes Required to Support On-Orbit Experiment Operations

	Crew Size		
	Single-Shift Capability	Multi-Shift Capability	
		Minimum	Preferred
Astronomy	2	4	4
Physics	2	4	4-6
Earth Observation	2	4	4
Comm/Nav	2	4	4
Matls Sci & Mfg	2	4	4
Technology	2-3	2-4	4-6
Life Sciences	3	4	6

4.2 FREE-FLYING RAM MISSIONS

4.2.1 MISSION OPERATIONS. The free-flying RAM delivery mission for the shuttle-supported mode begins with ground operations, including prelaunch checkout of the free-flying RAM (and RAM payload) and loading of the free-flying RAM into the orbiter (Figure 4-3). After boost to orbit by the shuttle, the RAM payload carrier is deployed from the cargo bay and experiment activation and checkout activities are initiated. Following preliminary on-orbit checkout of the free-flying RAM, the shuttle undocks from the RAM payload carrier and moves to a standoff position where ground stations control final experiment checkout.

Experiment operations are unmanned. The free-flying RAM supplies the required inertial and solar orientation, and guidance and navigation data is supplied from the ground. The payload carrier GN&C subsystem provides one arc-sec pointing accuracy and 0.5 arc-sec/observation pointing stability for celestial observations. Resources required for payload operation are also supplied by the free-flying RAM.

The shuttle can deliver payloads up to altitudes of 450 n.mi. and to orbits with a wide range of inclination angles to satisfy free-flying RAM payload requirements of orbit altitude from 240 to 400 n.mi. at inclinations of from 28.5 to 55 degrees. Orbit

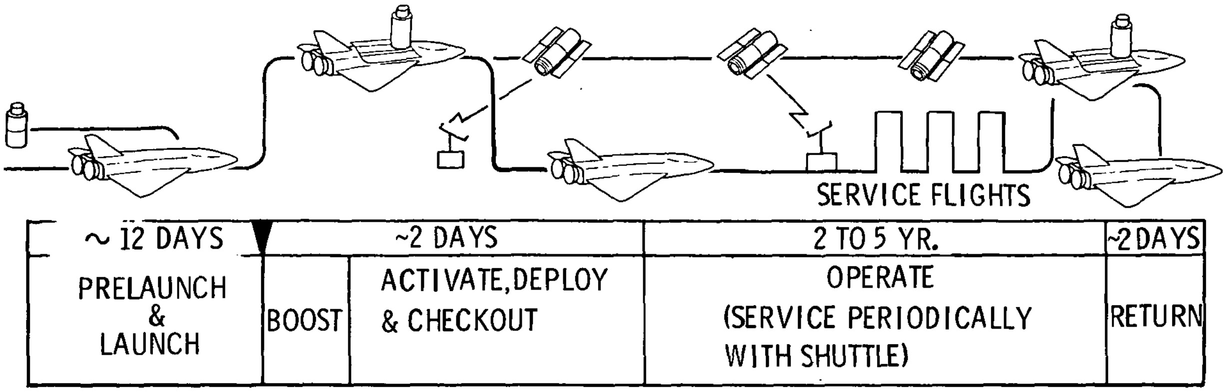


Figure 4-3. Free-Flying RAM Delivery Mission for Shuttle-Supported Mode

maintenance is provided periodically by the shuttle for operating altitudes below about 300 n.mi. The communications/data links between the free-flying RAM and the ground are the tracking data relay satellite (TDRS) and the ground network system. Experiment operations are conducted on orbit for about five years. The free-flying RAM is then returned to earth with the shuttle for refurbishment, recycle, or retrofit.

The station-supported free-flying RAM delivery mission is similar to the shuttle-supported mode when the RAM payload carrier is delivered to its operating position relative to the station. An alternative mode is to deliver the free-flying RAM to the station for initialization and checkout; in this case, the mission resembles the delivery portion of a station-attached mission.

Free-flying RAMs are serviced on orbit by either the shuttle with a sortie RAM or the space station. In the shuttle-supported mode, the free-flying RAM is visited periodically by the shuttle, which rendezvous with and docks to the free-flying RAM. In the station-supported mode, the free-flying RAM periodically translates and docks with the space station for servicing. In both cases, servicing is performed at 6- to 12-month intervals, as required.

During servicing, the free-flying RAM is pressurized after docking and crewmen enter the RAM payload carrier for maintenance. These activities include replacing failed, degraded, or marginal units; alignment; resupply of expendables; and other servicing necessary for the remotely controlled free-flying RAM operations. Following servicing operations, the shuttle undocks and stands off from the free-flying RAM (shuttle-supported mode) or the free-flying RAM undocks from the station and translates to a standoff position (station-supported mode). A series of test observations is then performed to verify that all free-flying RAM subsystems are functioning properly. The orbiter returns to earth (shuttle-supported mode) following the service operation. The free-flying RAM remains inactive for 24 to 48 hours while contamination and outgassing dissipate and thermal equilibrium is reached, then resumes normal operation.

4.2.2 CRITICAL OPERATIONS. Critical free-flying mission requirements are shown in Table 4-4. Experiment operations are conducted unmanned in the free-flying mode, with the RAM payload carrier supplying the required inertial or solar orientation. Guidance and navigation data is supplied to the free-flying RAM from the ground or by the station. In the shuttle-supported mode, the free-flying RAM is visited periodically by the shuttle for servicing, at which time the RAM payload carrier provides stabilization for docking of the shuttle. In the station-supported mode, the free-flying RAM performs rendezvous and docking maneuvers (RAM payload carrier active under station control) with the station for manned servicing. The station supplies resources for servicing and checkout.

The shuttle can satisfy free-flying RAM shuttle-supported payload requirements at orbital altitudes from 300 to 400 n.mi. at inclinations of from 28.5 to 55 degrees. The reference space station orbit is 240 to 270 n.mi. altitude at 55 degrees inclination. Station-supported free-flying RAM operations are co-orbital with the station, with orbit maintenance provided periodically by the free-flying RAM. The communications/data links between a shuttle-supported free-flying RAM and the ground are the TDRS and the ground network system (for the large space telescope). The station receives data from a station-supported free-flying RAM and transmits it to the ground via the TDRS. Shuttle and station free-flying RAM support requirements are similar except that the station-supported free-flying RAM propulsion is serviced periodically via umbilical connections, while the shuttle-supported free-flying RAM propulsion uses modular replacement when required.

Important user characteristics of the free-flying mission are also shown in Table 4-4. A simple experiment equipment attachment interface and the shirtsleeve and IVA service requirements are required for on-orbit maintenance/replacement operations. The free-flying RAM is designed for a nominal five-year orbital operation period between major refurbishments.

4.2.3 FREE-FLYING RAM MISSION CONSIDERATIONS. Three basic shuttle-supported free-flying RAM missions have been identified: delivery, servicing, and retrieval. Elements considered for use in these missions include the free-flying RAM, the sortie RAM, and an orbiter orbital maneuver subsystem (OMS) kit (for additional shuttle ΔV) housed in the orbiter cargo bay. The various combinations of these elements were assessed for each mission and cargo bay loading configurations and are shown in Table 4-5 using the LST payload as an example.

The LST is about 42.5 feet long with the sun shade retracted and weighs about 25,000 pounds at launch. Configuration options selected for each mission using the example LST payload are applicable to all representative free-flying RAM payloads.

Without an OMS kit, the orbiter has insufficient performance to deliver the free-flying RAM (delivery mission) to the operationally preferred orbit of 300 n.mi. by 40 degrees. Free-flying RAM delivery with a sortie RAM without an OMS kit is also

Table 4-4. Critical Free-Flying RAM Mission Operations Requirements

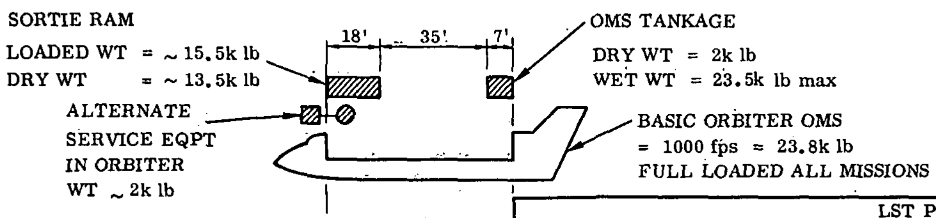
Function/Operation	Applicable RAM Element: Free-Flying RAM	Applicable RAM Element: Sortie RAM	RAM Payload Carrier Design Requirement: Shuttle-Supported Mode	RAM Payload Carrier Design Requirement: Station-Supported Mode
Free-Flying RAM Mission:				
Orientation	X		Inertial/Solar	Inertial/Solar
Guidance & Navigation	X		Ground supplied	By station
Rendezvous & Docking	X		Stabilization for shuttle docking	Active
Pointing - Accuracy	X		1 arc-sec	1 arc-sec
- Stability	X		1 arc-sec/obs†	1 arc-sec/obs†
Resources	X		Free-flying RAM supplied	Free-flying RAM supplied
Crew	X	X	Unmanned operation/man-serviced	Unmanned operation/man-serviced
Orbit	X		300 to 400 n. mi., 28.5 to 55 deg	Co-orbital with station - (270 n. mi., 55 deg)
Orbit Maintenance	X		Periodically by shuttle <350 n. mi.	Intermittent
Data Network	X		TDRS ground network system	Through station to TDRS/ ground network system
Experiment Equipment Interface	X		Easy experiment equipment changeout	Easy experiment equipment changeout
Orbit Life	X		5 yr between major refurbishment	5 yr between major refurbishment
RAM Environment	X	X	Shirtsleeve & IVA service pressurization/depressurization, mounting, access	Shirtsleeve & IVA service pressurization/depressurization, mounting, access
Free-Flying RAM Service:			Both Modes	
Storage				
Length		X	5 ft (maximum equip length)	
Volume/Weight				
- Experiment Equipment		X	88 cu ft (max)/2100 lb } 6-month service interval	
- Subsystem Equipment		X	25 cu ft (avg)/900 lb } 6-month service interval	
Test & Checkout Services		X	Power, data, communications	
Pressurization		X	One pressurization for free-flying RAM (and sortie RAM)*	
Propulsion Modules		X	Mounting (up to 4)*	
Crew		X	Minimum of 2	
Rendezvous & docking		X	Docking assembly, telescope mounting	

*Shuttle supported only
†More demanding stability (when required) provided by experiment or payload integration equipment.

unacceptable since orbiter performance is insufficient. The free-flying RAM, sortie RAM, and OMS kit combination is acceptable from a performance standpoint, but is too long to fit into the orbiter cargo bay. The selected free-flying RAM delivery option (shown in Table 4-5) is the combined free-flying RAM and OMS kit, since it meets both length and performance constraints. Orbiter performance data for the delivery mission is shown here for four inclinations (28.5, 40, 55, and 90 degrees). The free-flying RAM launch weight used in Table 4-5 is the total payload chargeable weight at liftoff, exclusive of the weight of the OMS kit and its propellant.

The only service mission configuration that is not constrained by performance or cabin space is the sortie RAM with an OMS kit, which is the selected service mode.

Table 4-5. Configuration Options — Shuttle Supported Delivery Service and Retrieval



Mission	Payload Combinations At Lift-Off	Bay Loading	LST Payload Data: Launch Length Total (ft)	Launch Weight RAM Total (k lb)	Maximum Altitude n. mi. @ Inclination 28 1/2°	40°	55°	90°	Acceptable	Shuttle Constraint (Primary)	Mode Selection
Delivery	FF (Free-Flying RAM)		42.5	25.0	270	270	270	255	No	Perf.	
	FF + OMS Kit		49.5	25.0	455	455	420	255	Yes	None	X
	FF + Sortie RAM		60.5	38.5	250	250	245	0	No	Perf. & Length	
	FF + OMS Kit + Sortie RAM		67.5	38.5	340	315	275	0	No	Length	
Service	Empty (serv in orbiter)		0	2.0	275	275	275	275	No	Perf. & Storage Space	
	OMS Only (serv in orbiter)		7	2.0	495	495	495	495	No	Storage Space	
	Sortie RAM Only		18	15.5	250	250	250	250	No	Perf.	
	Sortie RAM + OMS Kit		25	15.5	445	445	445	305	Yes	None	X
Retrieval	Launch - Empty / Return - FF		0 / 42.5	0	270	270	270	270	No	Perf.	
	Launch - OMS Kit / Return - FF + OMS Kit		7 / 49.5	0	490	490	490	490	Yes	None	X
	Launch - Sortie RAM / Return - FF + Sortie RAM		18 / 60.5	13.5	250	250	250	250	No	Perf. Length	
	Launch - Sortie RAM + OMS Kit / Return - FF + Sortie RAM + OMS Kit		25 / 67.5	13.5	445	445	445	310	No	Length	

The retrieval mission follows the same general pattern. Options without the OMS kit are performance-limited, and the option using sortie RAM, a free-flying RAM, and the OMS kit will not fit in the orbiter cargo bay. The selected retrieval mode option is to launch with the OMS kit and return with the free-flying RAM and dry OMS kit.

4.2.4 FREE-FLYING RAM ORBIT SELECTION. Selection of the preferred free-flying RAM orbit is influenced by several factors:

a. Unocculted Viewing Opportunities. The time available for continuous viewing of a celestial target is primarily a function of the orbit inclination and target declination. When these angles are complementary (i.e., where the viewing direction is near the normal to the orbit plane), viewing time is optimum and increases with increasing orbit altitude. If the object being observed is not near the normal to the orbital plane, earth occultation of the object occurs during each orbit. This interruption (up to one-half orbit) does not necessitate recalibration of instruments but does require guide-star reacquisition and relocation of the object before data can again be obtained. The potential time for continuous viewing is also reduced by periods required to unload (momentum) the CMGs and by periods in which the sensors are exposed to the high radiation flux of the South Atlantic anomaly.

b. High Energy Radiation. A radiation level of one millirad/hr has been specified in Volume I of the RAM Technical Data Document, GDCA-DDA71-003, Appendix A (Revision B) as the maximum level at which celestial observation instruments may be calibrated or used for source observation. Higher radiation levels can produce intolerably high noise levels during measurements and arcing of high voltage equipment, generally resulting in significant degradation of overall system performance. The South Atlantic anomaly region of the Van Allen radiation belt is a particularly significant source of this potentially harmful radiation (high energy electrons and protons). Therefore, observations must be performed outside those intervals where the radiation level at the instruments exceeds one millirad/hr because of entry into the South Atlantic anomaly.

   Figure 4-4 shows the amount of time spent in the South Atlantic anomaly as a function of orbit inclination and altitude. This data was derived from the one millirad/hour radiation limit and an estimated effective shielding of 0.75 gm/cm^2 ($\approx$0.1 inch) of aluminum. The dose rate resulting from electrons is more significant than the proton dose rate for this shielding thickness (by a factor of three in a 270-n.mi. altitude, 55-degree inclination orbit). Data in Figure 4-4 show the desirability of low-altitude orbits to avoid lengthy exposures to radiation levels greater than one millirad-hour.

c. Orbit Keeping. Figure 4-5 shows shuttle-supported, free-flying RAM orbit decay as a function of time in orbit. The free-flying RAM weight-to-area ratio is

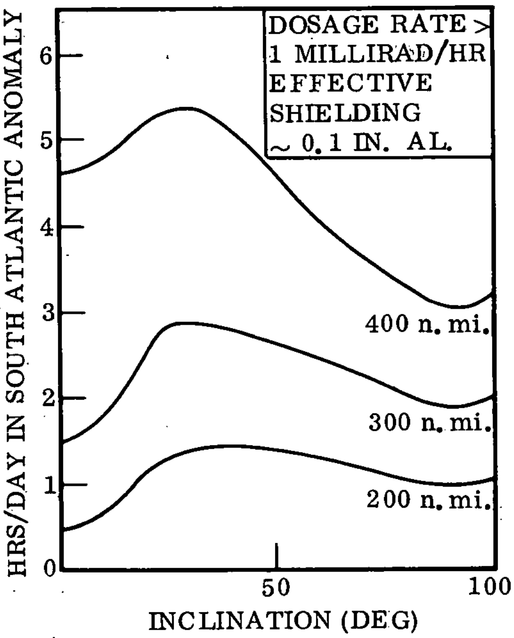


Figure 4-4. Exposure Time to South Atlantic Anomaly Radiation

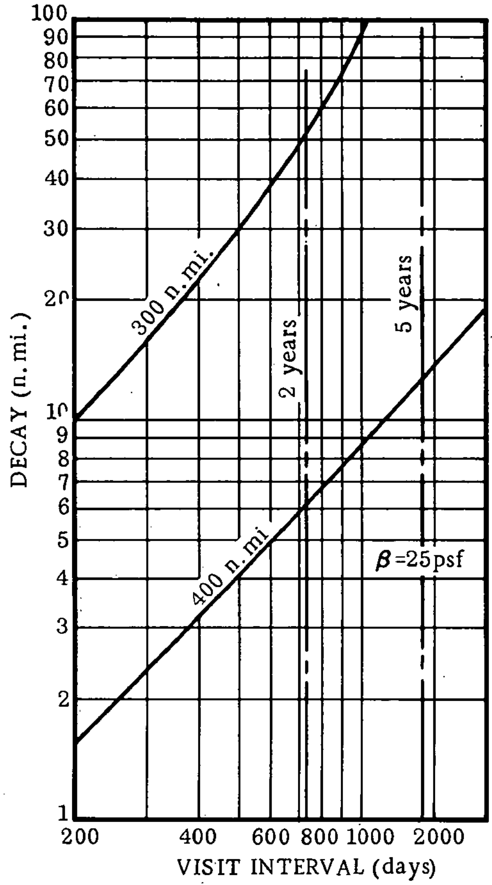


Figure 4-5. Orbit Decay Versus Visit Interval for Two Initial Orbital Altitudes

approximated at 25 psf. It is desirable to operate at the highest orbit consistent with shuttle delivery capability; for near-equatorial orbits, however, the Van Allen belt (and particularly the South Atlantic radiation anomaly) tends to drive the operating orbit to as low an altitude as possible consistent with long on-orbit stay times. The minimum orbital altitude without appreciable decay increases for free-flying RAM configurations with lower weight-to-area ratios. Figure 4-6 shows orbit-keeping propulsion velocity requirements as a function of orbital altitude for the maximum atmospheric density condition. If needed, orbit-keeping ΔV can be provided by the free-flying RAM propulsion system or by the space shuttle (consistent with shuttle performance and maintenance visit frequency).

d. Viewing Quality. Viewing quality can be measured in several ways. Six aspects of celestial source detection probability and viewing quality are given in Table 4-6, where they are quantified for the LST free-flying RAM payload. These factors are considered qualitatively correct for the other free-flying RAM missions, and the same trends with orbit altitude and inclination. Table 4-6 also

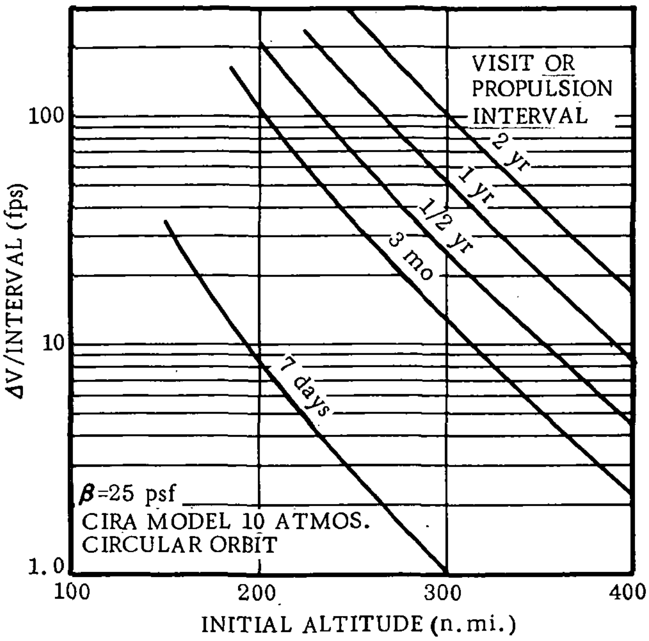


Figure 4-6. Orbit Keeping ΔV Requirements

contains quantitative data on viewing opportunities, radiation exposure, shuttle payload, and orbit keeping abstracted from the preceding discussions for the specific orbits compared.

Based on these discussions and the data summarized in Table 4-6, a 300-n.mi. by 40-degree orbit is selected as the recommended free-flying RAM orbit.

4.3 STATION-ATTACHED MISSIONS

4.3.1 MISSION OPERATIONS. The station-attached RAM is checked out and mated to the orbiter during prelaunch as shown in Figure 4-7. Following boost into orbit, the shuttle performs rendezvous with the space station, docks the RAM payload module to the station, and is then free to return to earth. RAM payload module is activated and checked out at the station.

For experiment operations, the required earth and inertial orientations guidance and navigation are supplied by the station. RAM payload module provides required pointing beyond the 0.25-degree pointing accuracy and 0.005-degree/second pointing stability provided by the station. Except for thermal control, resources required for payload operation are supplied to RAM payload module by the station. Periodically, the shuttle resupplies the station on logistics flight and the RAM payload module is serviced as needed.

The reference space station orbit is 240 to 270 n.mi. altitude at 55 degrees inclination. RAM payload module operations are conducted while attached to the station. The station processes, stores, or transmits data from the RAM payload module to the ground via the TDRS and ground network system. Experiment operations are conducted on orbit for periods up to five years. To return RAM payload modules to earth for refurbishment, recycle, or retrofit to a different payload, the RAM payload module is undocked from station by the shuttle, retracted into the shuttle cargo bay, and returned to earth inside the shuttle.

4.3.2 CRITICAL OPERATIONS. Table 4-7 summarizes critical requirements for station-attached mission experiment operations. Orientations required by the payload are supplied by the station. In addition, the station provides the stabilization, pointing, and resources to RAM payload module, which supplies resources and performance

Table 4-6. Factors Used in Selecting Recommended Free-Flying RAM Orbit (Large Space Telescope)

Factor	200 n. mi. 28.5 deg $\leq i \leq$ 55 deg	300 n. mi. 40 deg	400 n. mi. 28.5 deg
Viewing Quality			
Diffuse Source Detection Probability (percent)	50	99	99
Star Image Resolution, 1000 to 3000°A (arc-sec)	0.05	0.03	0.03
Sky Background, 5000 to 3000°A (Θ)	9×10^{-14}	5×10^{-14}	3×10^{-14}
UV Absorption, 2000 to 900°A (percent)*	2	0.05	0.001
Spectral Coverage (μm)	5.0 to 0.2	5.0 to 0.09	5.0 to 0.09
Brightline Spectral Interference	L	L	L
Viewing Opportunity			
Unocculted Viewing Opportunity, Optimum Targets (days)	7	14	17
Exposure Time to South Atlantic Anomaly Radiation (hr/day)†	1.5	2.8	5.4
Momentum Dumping Time	Function of telescope pointing direction		
Shuttle Payload to Orbit for Free-Flying Service (lb)	37,500 to 52,000	36,500	29,500
ΔV for Orbit Drag Makeup (fps/6 mo)	200	15	5

*If source is perpendicular to orbit plane.
†See Figure 4-4 for pertinent parameters.
Θ= Brightness of sun.

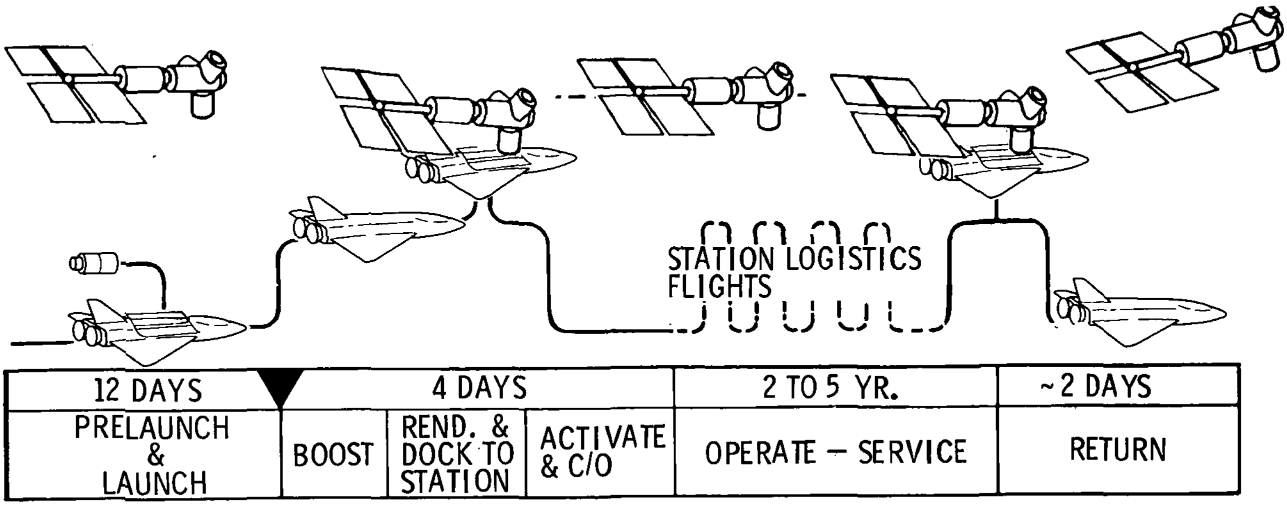


Figure 4-7. Station-Attached RAM Mission Operations

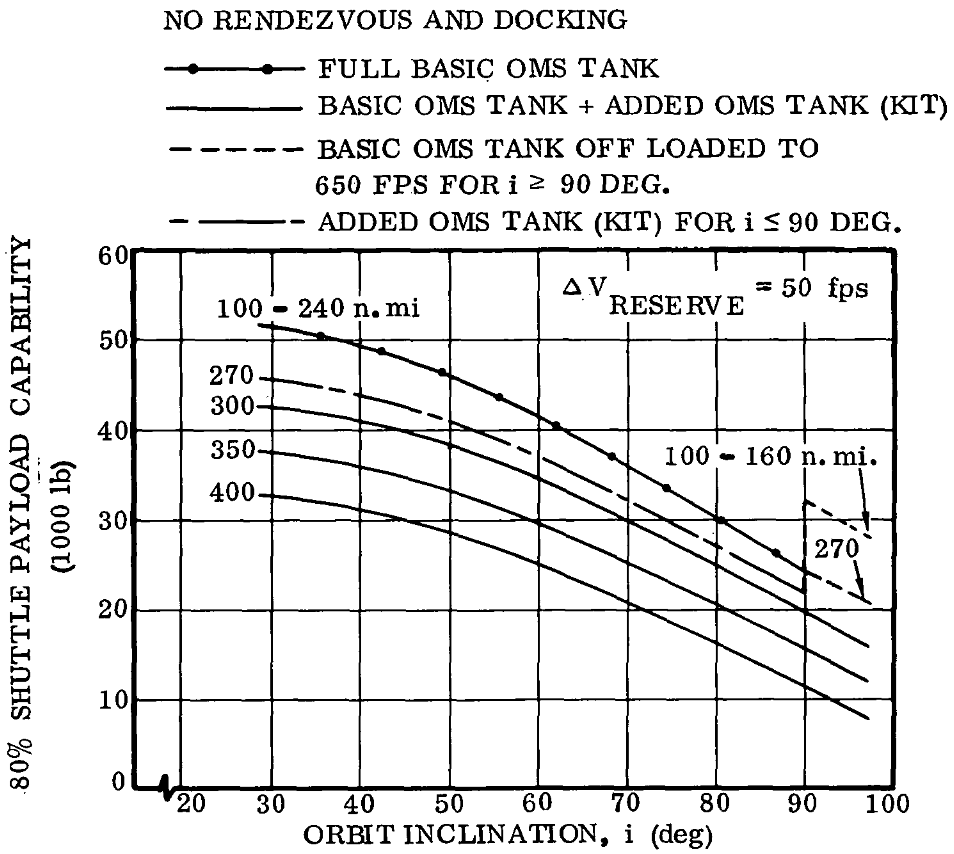
Table 4-7. Critical Station-Attached Mission Operations

Function/Operation	Applicability to Payload Module	RAM Design Requirement	Space Station Support or Constraint
Orientation		Earth/Inertial	Earth/Inertial Provided to RAM Payload Module
Guidance & Navigation		Provided by Station	±0.1 n.mi.
Rendezvous & Docking	X	Launch-to-Docking Resources	Controls Attitude During Docking
Pointing - Accuracy	X	Excess over Station (1 arc-sec)	±0.25 deg
- Stability	X	Excess over Station (0.5 arc-sec/sec)	±0.05 deg/sec
Resources	X	Excess over Station Capability	Provide to RAM Payload Module
Crew Habitability		Provided by Station	Up to 6 Crewmen
Orbit		Station Orbit	Ref 270 n.mi. by 55 deg
Data Network		Through Station	TDRS/Ground Network System
Range of Experiment Accommodation	X	Mounting, Access, Standard Interfaces	

capabilities exceeding station limitations. RAM payload module operations are conducted while attached to the station, which undergoes continuous orbit maintenance. Since the RAM payload module must accommodate a wide range of experiment equipment, adequate mounting and access space and standard interfaces are required.

4.4 RAM SYSTEM MISSION CAPABILITY

4.4.1 RAM SYSTEM WEIGHT TO ORBIT. Figure 4-8 shows maximum RAM payload carrier weight at shuttle liftoff as a function of operational orbit attitude and inclination



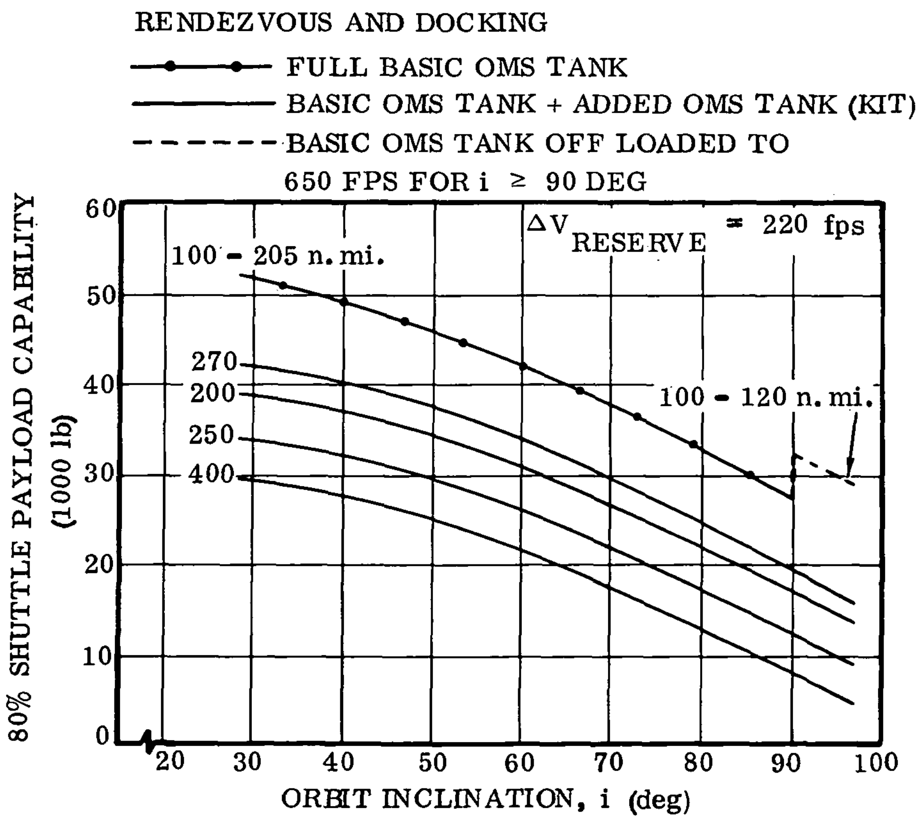


Figure 4-8. 80 Percent Shuttle Performance Capability

for two types of RAM mission: 1) no rendezvous and docking and 2) rendezvous and docking. The curves show the 80-percent payload capability of the orbiter. The data was derived from the Interface Requirements Document, which specifies:

a. For a due-east mission (28.5-degree inclination), the shuttle vehicle will be capable of carrying 65,000 pounds of payload into a 50 by 100 n.mi. orbit with the OMS tanks loaded with sufficient propellant for performing a translational velocity of 1000 fps.

b. For a polar mission (90-degree inclination), the shuttle vehicle will be capable of carrying into a 50 by 100 n.mi. orbit 40,000 pounds of payload with the OMS tanks loaded with sufficient propellant for performing a translational velocity of 650 fps.

c. The OMS propellant tank will be sized for 1000 fps for a due-east mission and a kit will be supplied to provide capability of 2000 fps. This OMS kit will be located in cargo bay and its weight and volume will be chargeable to the payload.

4.4.2 <u>SORTIE-MISSION ORBIT CAPABILITY</u>. Sortie mission payload orbit requirements and the capability of the shuttle to deliver payloads to the required orbits are summarized in Figure 4-9. Zero-g laboratories require only sufficient orbit altitude to provide a low-drag environment for experiments and to maintain the orbit over a seven-day sortie mission. An orbit altitude of 120 n.mi. satisfies both requirements. Low radiation doses are preferred for life science experiments. Preferred operating orbit characteristics for sortie-mission earth measurement payloads are high inclination (global coverage) and low altitude (maximum resolution). Sortie-mission celestial observation payloads prefer orbits with high altitude (maximum observation time) and low inclination (minimize exposure to South Atlantic anomaly radiation). A near-polar orbit is preferred for the solar astronomy payload.

Maximum estimated launch weights for sortie RAM and advanced mission configurations are shown in Figure 4-9. Shuttle payload capability (ABES out) in thousands of pounds (using RAM study guidelines of 80 percent capability available to RAM payload carriers) is plotted for orbits of interest to sortie-mission payloads. The discontinuity (at 90 degrees inclination) in the low-altitude performance curve is due to offloading propellant from the shuttle basic OMS tank for inclinations greater than or equal to 90 degrees. Shuttle payload capability is sufficient to deliver the maximum weight zero-g laboratory configurations to greater than the required 120 n.mi. altitude. Sortie RAM earth measurements configurations can be delivered to preferred polar orbits, while advanced-mission earth measurements configurations can be delivered to an acceptable orbit in all cases. Sortie RAM mission celestial observations configurations can be delivered to preferred orbits — sun synchronous at 200 n.mi. altitude is the most demanding case. Advanced-mission celestial observations configurations can be delivered to acceptable orbits in all cases.

PAYLOAD ORBIT REQUIREMENTS		
PAYLOAD. TYPE	PREFERRED ORBIT	ACCEPTABLE ORBIT
ZERO-g	>120 N.MI. x ANY INCL.	>120 N.MI. x ANY INCL.
EARTH MEAS.	100 N.MI. x 50° - 90°	100 N. MI. x 50°
CELESTIAL OBS	200 - 400 N.MI. x 28.5° - 55°, 97°	200 - 270 N.MI. x 28.5° - 45°

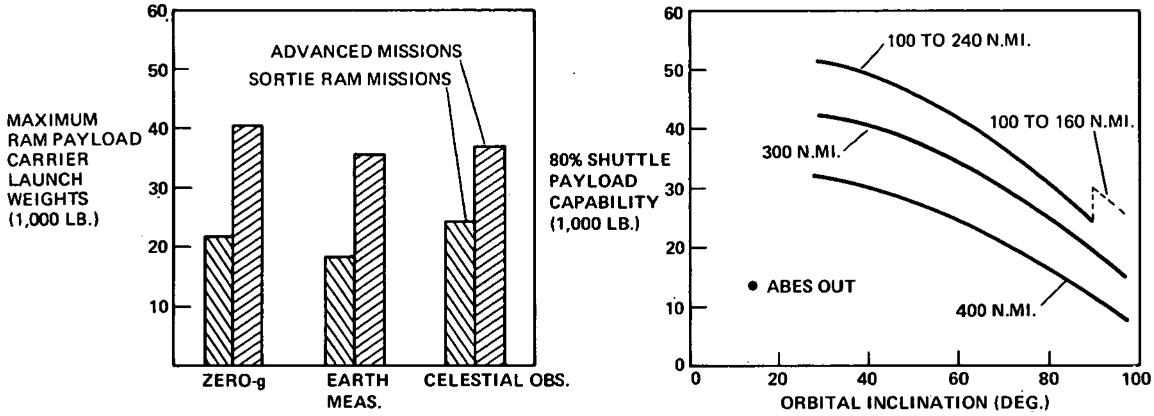


Figure 4-9. Sortie Mission Capability

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 5

OPERATIONS ANALYSIS

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SECTION 5

OPERATIONS ANALYSIS

RAM elements perform operations in three basic mission modes: 1) sortie, 2) free-flying (including delivery, servicing, and retrieval), and 3) station-attached. The five mission phases shown in Table 5-1 are common to all RAM missions. The table also identifies critical mission operations during each mission phase.

Table 5-1. Mission Phase and Critical Operations

Prelaunch/ Launch	Boost (Entry) and Preparation	On-Orbit Operations	On-Orbit Servicing	Postflight
Installation Mate Service Checkout Transport	Cargo Bay Doors Open (Closed) Checkout Deployment/ (Retraction)	Orientation Rendezvous and Dock Stationkeeping Payload Operations Satellites Airlock EVA/IVA Environmental Control	Repair/Replace Replenish Expendables Equipment Update Checkout (Attached and Detached)	Data/Specimen Removal Off-loading/ Safe Maintain/ Refurbish

Prelaunch operations require that the RAM payload carriers provide horizontal and vertical access for equipment installation or checkout and installation of time-critical items. RAM payload carrier subsystems such as onboard checkout and controls and displays are used to support ground operations. Other subsystems are actuated primarily for ground testing, with GSE interfacing with RAM payload carrier subsystems and providing the necessary support during ground operations.

Boost and entry operations have similar impacts on RAM payload carrier subsystems. Reduced levels of RAM payload carrier functional operations can be expected during these periods. RAM deployment and subsystems checkout during the preparation for on-orbit experiment periods are the first on-orbit operations requiring a significant degree of man involvement.

On-orbit operations require close cooperation between the orbiter crewmen and RAM crewmen for orientation, rendezvous and docking operations, and stationkeeping (orbit maintenance). Man involvement is maximum during the experimentation phase, with orbiter support (orientation, EVA monitoring, contamination control, stabilization, communications) and maximum RAM payload carrier resource supplies required.

Postflight operations commence with orbiter landing. Data and specimens are off-loaded, some of which are time-critical. The RAM payload carrier is safed and demated from the orbiter, and maintenance and refurbishment are accomplished in preparation for the next mission.

Key operations during these mission phases impact RAM payload carrier subsystems as summarized in Table 5-2.

Table 5-2. Impact of Key Mission Operations on RAM Payload Carrier Subsystems

Subsystem	Mission Phase				
	Prelaunch	Boost (Entry) and Preparation	On-Orbit Operations	Servicing	Postflight
Electrical Power	Ground Interface and Test	Reduced Load	Full Load	Full Load	Reduced Load
Thermal Control	Ground Interface and Test	Reduced Load Bay Environment	Full Load Space Environment	Full Load Space Environment	Reduced Load Bay Environment
Structure	Transport Loads Handling Fittings Vertical-Horizontal Access	Flight Loads Deployment/Retraction Positive Pressure Vent Interface	Docking Loads Maneuver Loads	Storage Zero-g Access	Data Removal Crew Egress Standard Interface
EC/LS	Ground Interface and Test	Crew Support	Crew Support	Crew Support	Crew Support
Habitability	Ground Operation	Up to 4 Crew	Up to 4 Crew	2 Crew	Ground Operation
GN&C	Ground Test	CMG Spinup (Sortie)	Rendezvous and Dock Orientation and Pointing	Full Operation	None
Propulsion (Free-Flying RAM)	Ground Test	None	Stationkeeping	Rendezvous and Dock (Station Supported) Dock (Shuttle Supported) Zero-g Resupply (Station Supported) Exchange RCS Elements (Shuttle Supported)	Safing
Comm/Data	Ground Interface and Test Ground Operation	Reduced Data Caution and Warning	Full Data Space Operation	Full Data Space Operation	Voice Checkout
Controls and Displays	Ground Operation	Space Operation	Space Operation	Space Operation	Ground Operation

Sortie missions accommodate both early-mission and later-mission payloads. The early-capability missions use a sortie RAM that may have a RAM pallet attached for specific payloads requiring an additional unpressurized payload-mounting area. The later-capability missions use a RAM support module (RSM) or sortie RAM mated with a RAM payload module, which may have a RAM pallet attached. There are four sortie mission configurations: 1) sortie RAM, 2) sortie RAM plus RAM pallet, 3) RSM or sortie RAM plus 18- or 32-foot RAM payload module, and 4) RSM or sortie RAM plus 18-foot RAM payload module plus RAM pallet. There are two free-flying RAM mission launch/entry configurations: 1) free-flying RAM (delivery, retrieval) and 2) sortie RAM (service). Because of orbiter cargo bay length restrictions, a free-flying RAM and a sortie RAM can not be accommodated with the orbiter vehicle's orbital maneuver sub-system (OMS) kit in the cargo bay at the same time. The two station-attached mission

RAM payload carrier configurations are: 1) 18-foot RAM payload module and 2) 32-foot RAM payload module.

5.1 FLIGHT OPERATIONS

5.1.1 SORTIE MISSION. A flight operations profile for the RAM sortie mission is shown in Figure 5-1. Flight operations begin with the launch of the shuttle (the RAM crewmen board at T -1 hours). After orbiter separation from the booster and insertion into the transfer ellipse orbit, the orbiter cargo bay doors open, exposing RAM element thermal radiators for temperature control. A Hohmann transfer to circular orbit at the desired operational orbit altitude is completed about 1.5 hours into the mission. One hour is then estimated for orbiter checkout. Following boost and ascent to orbit, RAM payload carrier deployment (if required) from the orbiter cargo bay is accomplished by manipulator or deployment mechanisms. It will then take 6.5 hours for on-orbit checkout of the RAM payload carrier and the payload. After all checkouts have been completed satisfactorily, the Go for payload operations is given. During the six days of payload on-orbit operations, a two-man RAM crew works together typically on a one-shift-on/one-shift-off basis (12 hours experimentation time/day average). A four-man or greater RAM crew typically works around the clock (two men per shift). About 2.5 hours per day are required for daily subsystems operations and maintenance tasks.

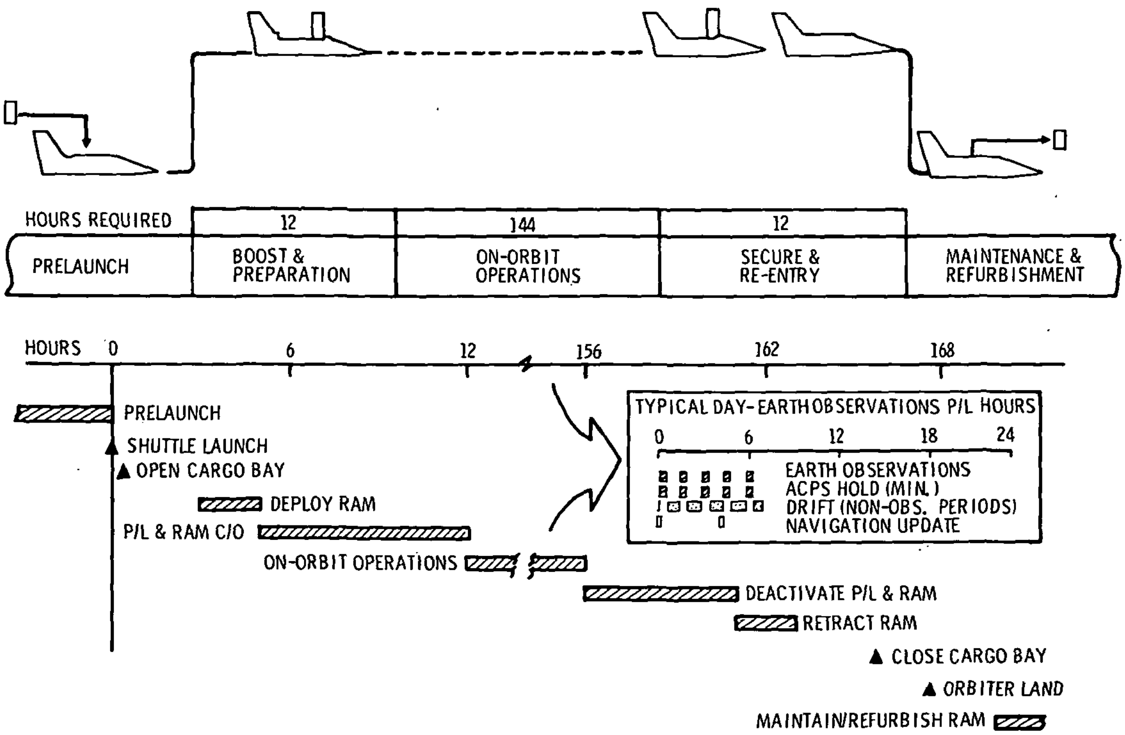


Figure 5-1. Sortie Mission Operations

Following payload operations, 6 hours are needed to deactivate and safe the RAM payload carrier and the payload. RAM payload carrier is then retracted into the orbiter cargo bay. Nominal orbiter earth-return operations require about 4 hours for entry preparation and proper phasing for landing. Cargo bay doors are closed just prior to deorbit. Orbiter vehicle landing is indicated at 168 hours elapsed time from launch. Systems Go at each of the major decision points (e.g., orbit stay, RAM payload carrier deployment) is typically verified by use of caution and warning indications, checkout data, and visual checks prior to proceeding into the next operation.

Inset in Figure 5-1 is an example Earth Observations timeline. Short checkout periods precede the viewing opportunities, and data acquisition periods range up to about 25 minutes while the shuttle holds pointing accuracy at ±0.5 degree. Contamination covers are, of course, open during viewing periods, therefore, it is desirable to limit shuttle ACPS firing to those thrusters directed away from the sensitive instruments on the RAM payload carrier. During intervals between viewing periods, shuttle attitude is controlled to about ±20 degrees to reduce fuel consumption. Navigation updates are received from orbiter contacts with ground network.

5.1.2 FREE-FLYING RAM DELIVERY MISSION. A typical operational timeline for the shuttle-supported, free-flying RAM delivery mission is shown is Figure 5-2. Manned RAM operations are based on a payload crew of two working one 12-hour shift per day. After prelaunch ground operations, the free-flying RAM is boosted into orbit by the shuttle. Free-flying RAM subsystems are active during boost (and ascent), providing support to the payload. After orbiter maneuvering to the RAM operational orbit, the RAM payload carrier is deployed from the orbiter cargo bay. After verifying free-flying RAM safety, crewmen enter the free-flying RAM to activate the subsystem and payload and to verify that they are functioning properly to perform experiment operations. Checkout emphasis is placed on those systems required for safety and the release and possible retrieval of the free-flying RAM. Resources for these activation/checkout operations are supplied by the free-flying RAM and the orbiter vehicle with or without a sortie RAM, depending on the combined length of a sortie RAM and the representative free-flying RAM payloads.

Solar arrays on the free-flying RAM are deployed early to provide power for subsequent operations. Prior to release, the free-flying RAM is depressurized while attached to the orbiter. Following checkout of the depressurized RAM (payload carrier and the payload), the orbiter undocks from the free-flying RAM and moves to a standoff position where the ground controls final free-flying RAM and experiment checkout. A period is provided for initial contamination clearing of outgassed material and propulsion effluents. Experiment instruments are then verified. After on-orbit checkout is completed, the orbiter returns to earth. The free-flying RAM may remain inactive for a period of 48 hours to provide additional time for outgassing, thermal equilibrium, or battery charging. At the end of this period, the free-flying RAM starts scientific observations.

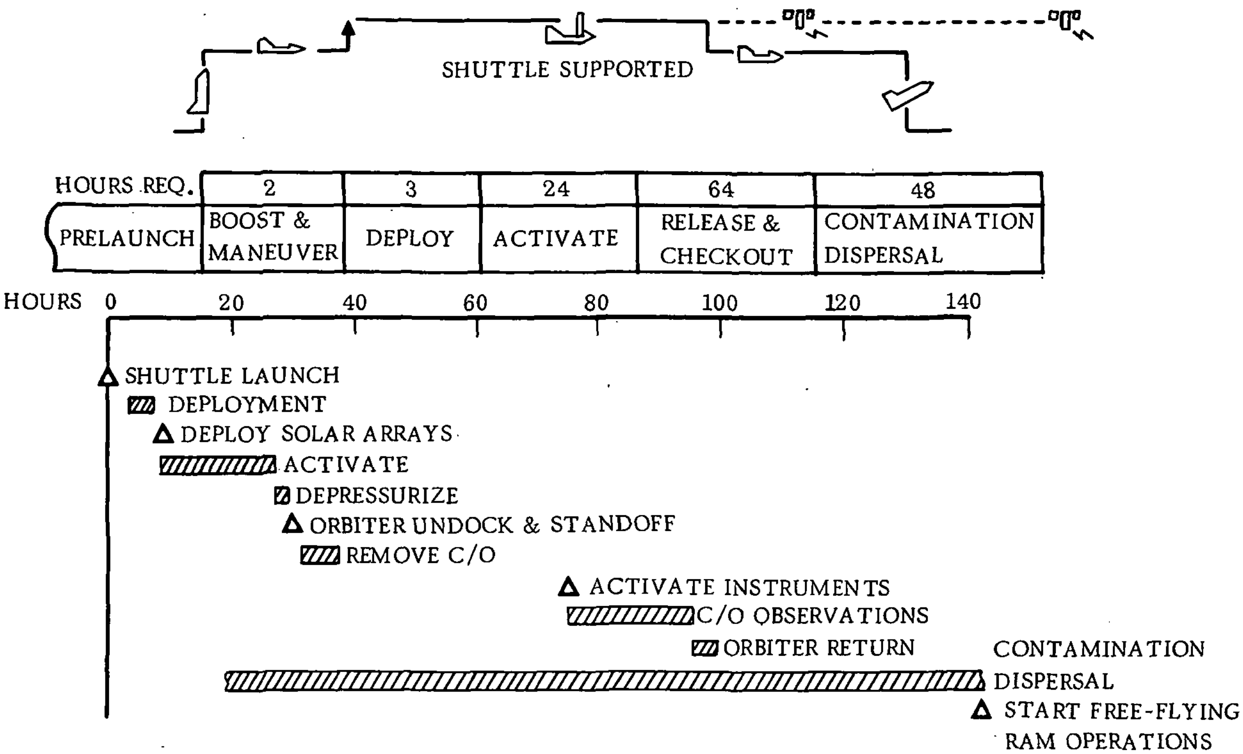


Figure 5-2. Free-Flying RAM Delivery Mission Operations

The operational timeline for the station-supported, free-flying RAM delivery mission is similar to that for the shuttle-supported free-flying RAM except that additional orbiter maneuvering time is required after boost to rendezvous at the proper station-keeping position relative to the space station. In the station-supported mission, the orbiter is free to return to earth shortly after free-flying RAM release. Checkout in orbit is then accomplished under station control.

5.1.3 <u>FREE-FLYING RAM SERVICE MISSION</u>. A typical free-flying RAM service mission operational timeline for the shuttle-supported mode is shown in Figure 5-3. Again, on-orbit free-flying RAM manual operation times are based on a payload crew of two working one 12-hour shift per day. Following shuttle launch (with a sortie RAM to perform the servicing) and orbit insertion, free-flying RAM experimental operations are terminated (in sufficient time for thermal equilibrium to be established prior to manned entry) and the instruments are closed for contamination protection. The orbiter then maneuvers to rendezvous (timeline implies worst-case phasing) with the free-flying RAM. After rendezvous, the sortie RAM is deployed from the orbiter cargo bay and the orbiter/sortie RAM is docked to the free-flying RAM. The free-flying RAM is then pressurized and crewmen enter it and begin maintenance. Resources (e.g., power) are supplied by the sortie RAM through manually connected umbilicals. Maintenance activities include replacing failed, degraded, marginal, or obsolescent units; alignment; resupply of expendables; and other servicing necessary for the remotely controlled free-flying operations.

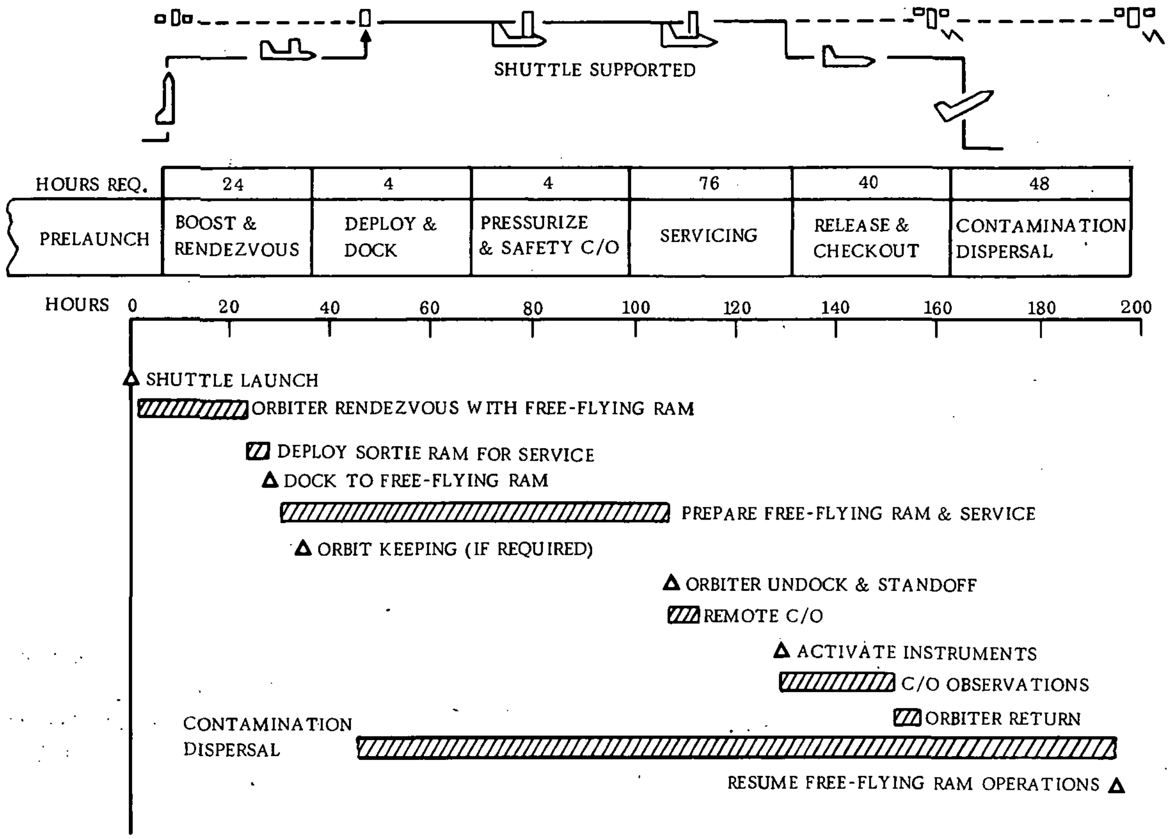


Figure 5-3. Free-Flying RAM Service Mission Operations

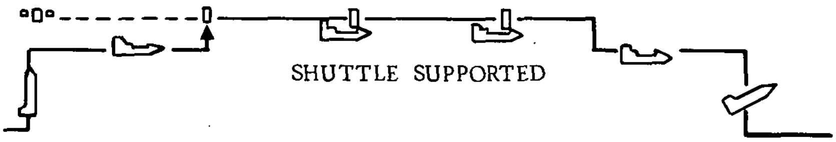
The remainder of the free-flying RAM service mission operations sequence, from depressurization through release and detached checkout, is almost identical to that for the free-flying RAM delivery mission. The major difference is that for the service mission only about 24 hours are required for contamination clearing before opening the telescope following depressurization. This is because a large portion of the free-flying RAM has not recently been exposed to the ground environment. The orbiter starts earth-return operations after on-orbit checkout is completed.

The operational timeline for the station-supported, free-flying RAM service mission is similar to that of the shuttle-supported mode. In the station-supported mode, the free-flying RAM must rendezvous and dock with the space station after the payload is deactivated under control of the station. Rendezvous maneuver time can vary from one to several orbit periods, depending on the stationkeeping distance and rendezvous propellants expended. After maintenance at the station using station-supplied resources, the free-flying RAM undocks from the station and deploys to its checkout or stationkeeping position. On-orbit checkout is then conducted under control from the station.

5.1.4 <u>FREE-FLYING RAM RETRIEVAL MISSION</u>. At planned major refurbishment intervals (five years) or in the event of a system failure of the free-flying RAM that cannot be repaired on-orbit, a manned shuttle flight will rendezvous and dock with the free-flying RAM and return it to earth in the orbiter cargo bay.

A timeline of the retrieval mission for a shuttle-supported free-flying RAM is shown in Figure 5-4. The shuttle is launched into an initial circular orbit, from which it transfers into the free-flying RAM orbit. Prior to transfer, the free-flying RAM terminates experimental operations. After rendezvous is achieved, the orbiter docks with the free-flying RAM. The RAM element is then pressurized and all subsystems not required for entry are systematically shut down, safed, and secured for return to earth by the retrieval crew. The free-flying RAM is retracted into the orbiter payload bay and secured. Finally, the standard shuttle de-orbiting procedure is executed and the orbiter returns to earth, about 39 hours after launch.

The timeline for the station-supported free-flying RAM retrieval mission is the same as for the shuttle-supported mission if the free-flying RAM is picked up at its station-keeping position. If the free-flying RAM should be retrieved at the station (e.g., because an unrepairable failure was encountered while the free-flying RAM was being serviced at the station), the timeline would differ due to docking and undocking operations and preparation of the free-flying RAM for entry prior to arrival of the shuttle.



HOURS REQUIRED	24	1	4	6	4	
PRELAUNCH	BOOST & RENDEZVOUS	SECURE & DOCK	PRESSURIZE & SAFETY C/O	SHUTDOWN & RETRACTION	RETURN TO EARTH	POST LANDING

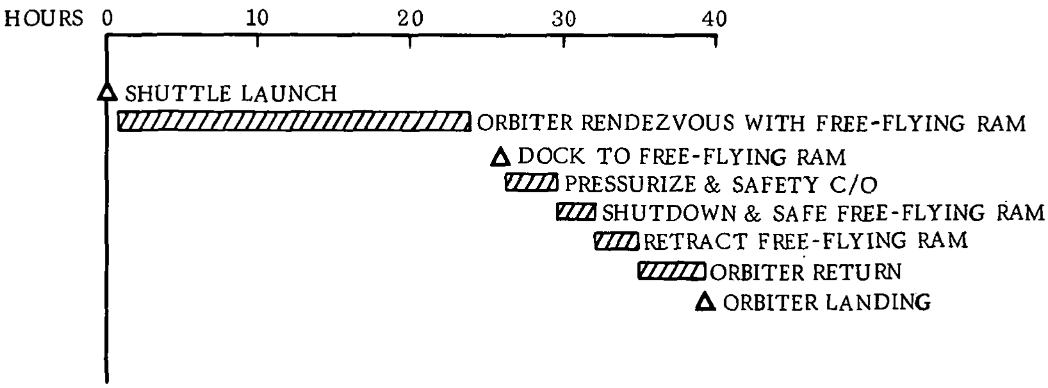


Figure 5-4. Free-Flying RAM Retrieval Mission Operations

5.1.5 <u>STATION-ATTACHED RAM MISSION</u>. In the delivery mission (Figure 5-5), the shuttle delivers and docks a RAM payload module to the space station. The 24 hours shown on the timeline to achieve rendezvous is a maximum value and represents a worst-case phasing condition at shuttle launch. After rendezvous is achieved, the orbiter deploys the RAM payload module from the cargo bay. A visual inspection of the RAM payload module is conducted prior to docking to ensure structural integrity has been preserved during boost and deployment. The station crew attaches RAM/payload module station interconnects and verifies RAM payload module habitability after it is

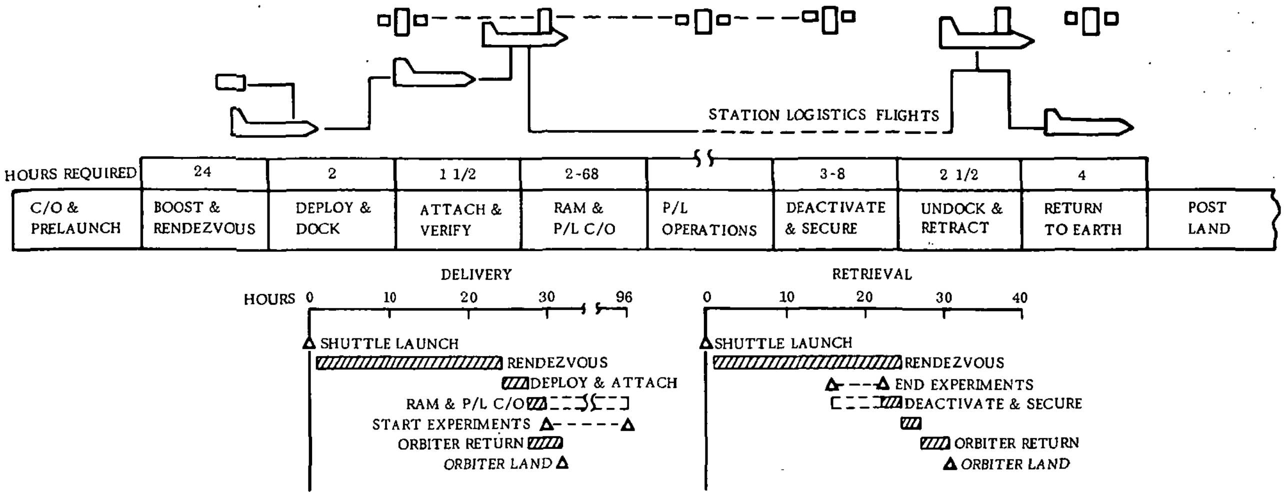


Figure 5-5. Station-Attached RAM Mission Operations

docked to the station. The station crew then opens the hatch to the RAM payload module and begins subsystem and payload checkout. Payload checkout takes from 2 to 68 hours, depending on the payload. Station-attached RAM payload operations begin after 29 to 96 elapsed time from launch. The orbiter is free to return to earth after the payload is docked to the station. Orbiter mission time for delivery of a RAM payload module to the space station is 32 hours.

Experiment operations are conducted on orbit for up to five years, with expendables supplied via shuttle logistics flights. At the conclusion of the on-orbit experimentation period, the RAM payload module is returned to earth by the shuttle for refurbishment, recycle, or retrofit to a different payload.

In the retrieval mission, Figure 5-5, the shuttle undocks a RAM payload module from the station and returns the module to earth. Shuttle retrieval operations are the same as the delivery mission through rendezvous with the space station. RAM payload operations are terminated in anticipation of orbiter retrieval, and the RAM payload module and its payload are deactivated and secured for entry prior to arrival of the orbiter. A 3- to 8-hour period (depending on the payload) is required for this deactivation and securing operation. The orbiter undocks the RAM payload module from the station and retracts it into the cargo bay. With a nominal orbiter return time of 4 hours for final checks and orbit phasing, the shuttle mission time for the station-attached RAM payload module retrieval mission is 30.5 hours.

5.2 GROUND OPERATIONS

Ground operations for the RAM elements include the following phases.

a. RAM payload carrier/Payload Integration. Operations required to install, calibrate, align, and verify the mutual compatibility of RAM payload carrier, experiments, and experiment integration equipment. All RAM elements except RSMs will pass through this operational phase whenever a new payload is to be installed.

b. Prelaunch Operations. Operations required to prepare the integrated RAM payload carrier and payload for shuttle launch operations, including assembly of equipment as required, weight and balance, servicing, and mating with the orbiter. The RSMs enter the operations loop in this phase.

c. Launch Operations. RAM element and payload operations required during shuttle launch operations, including servicing with hazardous and perishable items, crew embarkation, and changeover to flight systems.

d. Postflight Operations. RAM element and payload operations required between orbiter landing and the beginning of RAM element/payload maintenance and refurbishment operations. Included in this phase are passivation and safing, data removal, crew debarkation, and demating of RAM element/payload from the orbiter.

e. Maintenance and Refurbishment. Operations required to prepare a RAM element and payload that have been returned from orbit for the next mission (integration or prelaunch, as appropriate). Operations include demating RAM elements as required, scheduled and unscheduled maintenance and repair, updating of subsystem equipment as required, and removal of payload and experiment integration equipment not required for the next mission.

Figure 5-6 depicts the RAM element flow through ground operations, showing the major ground operation phases. These are examined in more detail in the following sections.

Figure 5-7 is a timeline for a typical sortie RAM turnaround from landing to liftoff, with a payload changeout. This timeline is based on analysis of representative sortie RAM Earth Observations and Communication/Navigation discipline payloads and shows a ten-week turnaround. Other payloads might require somewhat shorter or longer timespans for payload integration. If a payload is to be reflown, the payload integration phase is not required and the prelaunch operations phase is shortened by about three days, so turnaround could be accomplished in less than five weeks.

5.2.1 <u>RAM PAYLOAD CARRIER/PAYLOAD INTEGRATION.</u> Figure 5-8 shows a typical flow for RAM payload carrier/payload integration operations. The flow shown is based on the assumption that a new RAM element and a new payload are being brought together for the first time at an integration site that is different from the respective manufacturing sites. There are several parallel operations occurring in the first part of the integration operations. The RAM payload carrier, experiments, experiment

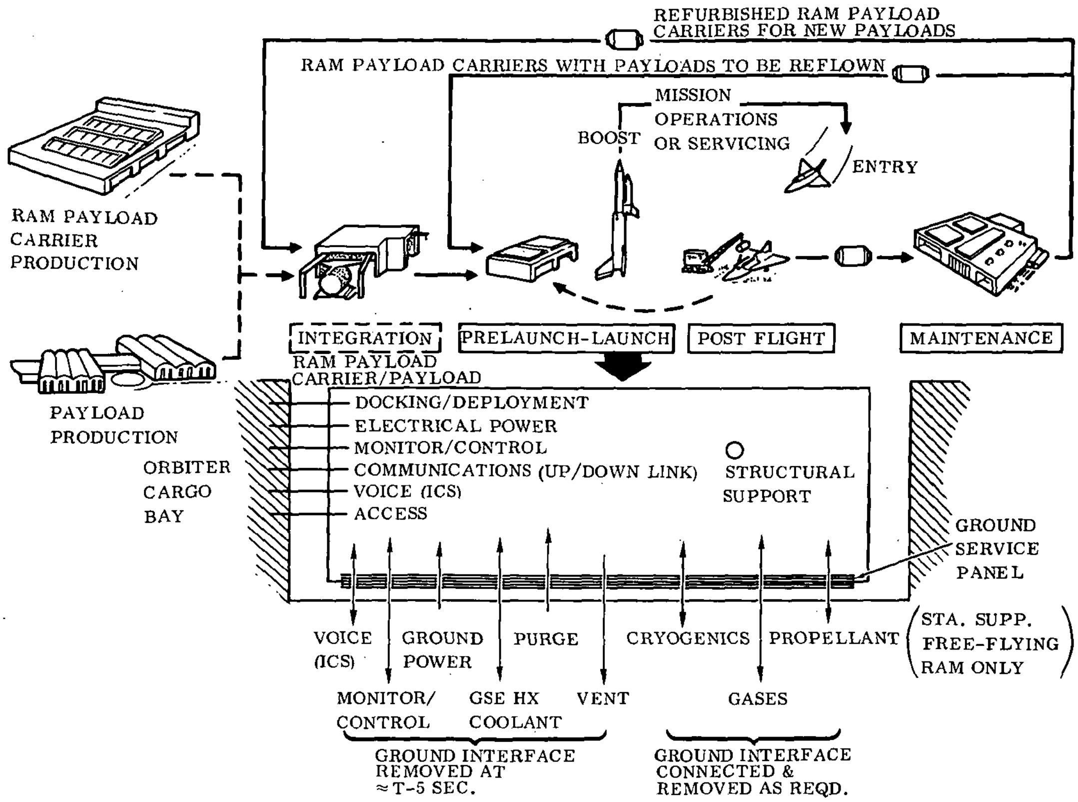


Figure 5-6. Ground Operations Flow

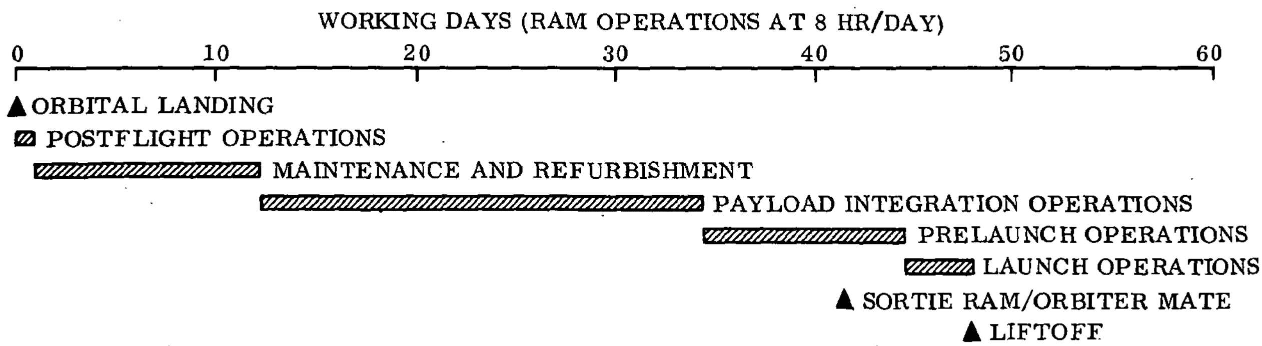


Figure 5-7. Typical Sortie RAM Turnaround Timeline

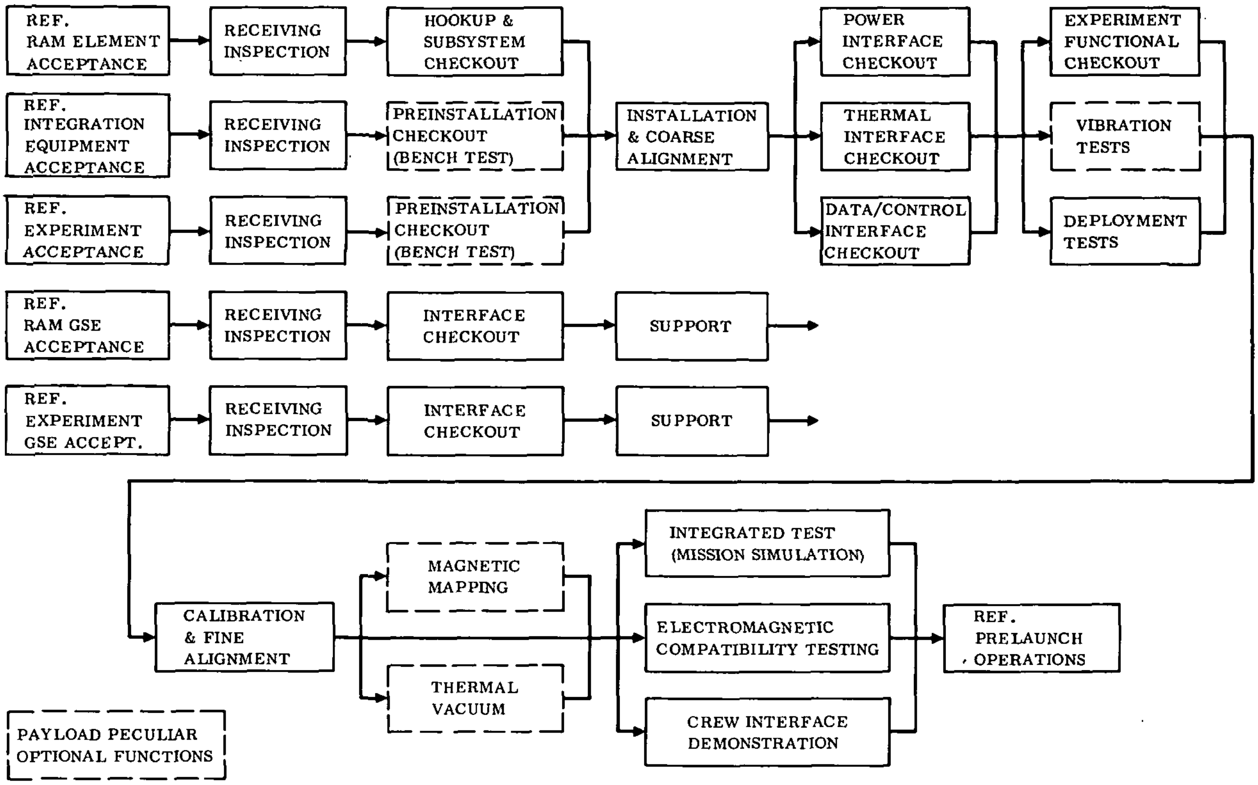


Figure 5-8. Typical RAM Payload Carrier/Payload Integration Flow (see Figure 5-7)

integration equipment, and GSE are all received from production acceptance and undergo a receiving inspection to verify that there is no shipping damage. Reference blocks in the figure indicate interfacing functions as appropriate.

While the RAM element is hooked up and subsystem checkout is accomplished, preinstallation tests are performed on experiment equipment and experiment integration equipment to ensure readiness for installation. GSE interfaces are checked out to ensure compatibility with RAM element and the payload for succeeding operations.

As readiness of all equipment for installation is verified, installation is begun. The details of this operation depend on the specific payload. Large sensors that require external viewing are generally installed either on experiment-peculiar end bulkheads or on RAM pallets. Typically, a minimal level of alignment is accomplished to support the succeeding checkout operations. The next phase of operations consists of verifying the power, thermal control, and data and control interfaces between payload equipment and the RAM payload carrier subsystems. This may be done incrementally during the installation process, if appropriate. Functional tests of the installed equipment and deployable mechanisms are accomplished next, as well as payload vibration tests (if required).

After completing the post-installation checkout operations, fine alignment, installed calibrations, and major payload-required special tests (e.g., magnetic mapping and thermal vacuum) are accomplished.

The final phase of integration operations is a combined system test phase that includes an electromagnetic compatibility (EMC) demonstration and a mission simulation, which also serves as a crew interface demonstration. On completion of the integrated system test phase, the RAM element and payload are prepared for prelaunch operations.

The RAM element/payload may be used for crew training upon completion of integration and before the start of prelaunch operations or it may be stored for short periods while awaiting launch opportunities.

5.2.2 PRELAUNCH OPERATIONS. Figure 5-9 shows a typical functional flow for the prelaunch phase. The RAM elements with installed payloads enter this phase of operations from either RAM element/payload integration (newly installed payloads) or maintenance operations (payloads being reflown). If the mission is an advanced sortie mission, the RAM payload module containing the experiments is mated with the RSM which will provide subsystem support for the upcoming mission) and the interface between these elements is verified. Servicing of non-perishable, non-hazardous consumables, spares, etc. is accomplished next, along with weight and balance verification for new payloads.

The RAM payload carrier/payload is then transported to the orbiter maintenance and checkout facility, installed in the payload bay with orbiter in a horizontal position, and the RAM payload carrier/orbiter interfaces verified. On completion of orbiter/booster mate and other prelaunch operations, the shuttle (with RAM payload carrier/payload aboard) enters launch operations.

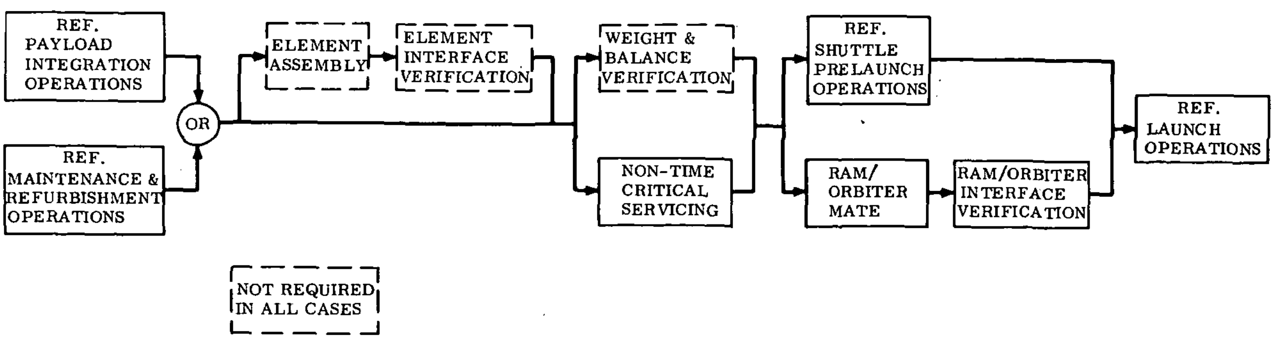


Figure 5-9. Typical Prelaunch Operations Flow (see Figure 5-7)

5.2.3 LAUNCH OPERATIONS. The launch operations phase begins with transportation of the mated shuttle to the launch pad. Figure 5-10 shows a typical functional flow for RAM payload carrier launch operations. RAM element/payload operations are keyed to the shuttle launch operations (i.e., servicing operations are accomplished at about the same time as similar shuttle operations, the payload crew boards with the shuttle crew, and the RAM payload carrier switches over to the inflight condition at about the same time as the shuttle.)

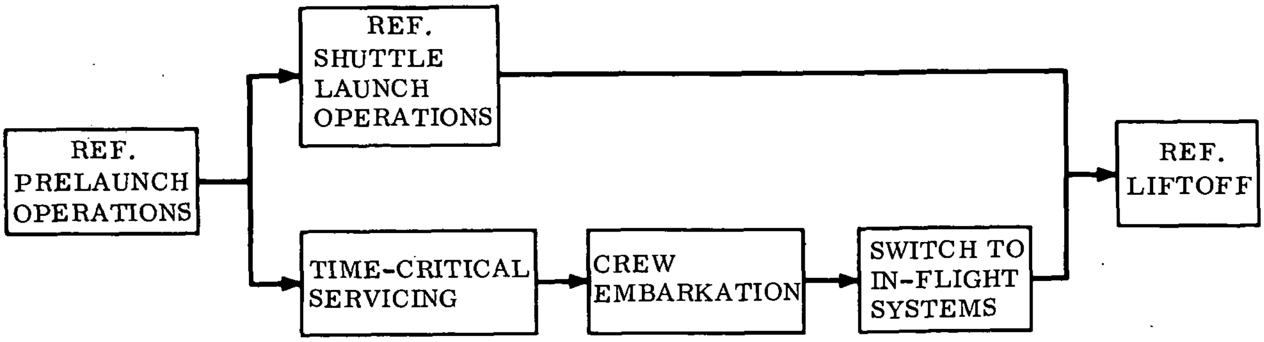


Figure 5-10. Typical Launch Operations Flow (see Figure 5-7)

Time-critical servicing for RAM payload carrier consists of loading fuel-cell cryogenic reactants and high-pressure nitrogen. In addition, certain payloads have requirements for servicing with time-critical items such as cryogenics, gases, and biological specimens.

The Payload crew boards the orbiter with the shuttle crew and up to two of the payload crewmen are accommodated in the orbiter crew compartment. For more than two, the additional payload crewmen are accommodated in the RSM, to which they gain access by means of a ladder from the shuttle airlock.

The changeover to flight systems for the RAM element means essentially switching to onboard power and thermal control. The power changeover is accomplished at about T-1 minute and the thermal control changeover as late as possible (probably about T-5 seconds).

5.2.4 POSTFLIGHT OPERATIONS. Figure 5-11 shows a typical functional flow for postflight operations. These operations are accomplished in three different facilities. After landing, the orbiter proceeds to a passivation and safing area, where the payload crew debarks, time-critical data and/or experiment specimens are removed, and payload carrier subsystems and payload equipment are safed. Requirements for safing consist primarily of venting and purging of reactants and high-pressure gases.

After the orbiter, RAM element, and payload are safed, the orbiter is towed to its maintenance facility. The RAM element and payload are dormant during this period, except that some payloads with stringent thermal control requirements may have thermal control equipment operating.

After arrival in the orbiter maintenance facility, RAM element/payload is removed from the orbiter cargo bay and delivered to the maintenance and refurbishment facility. The remaining data from the mission is removed and delivered to the users, concluding postflight operations.

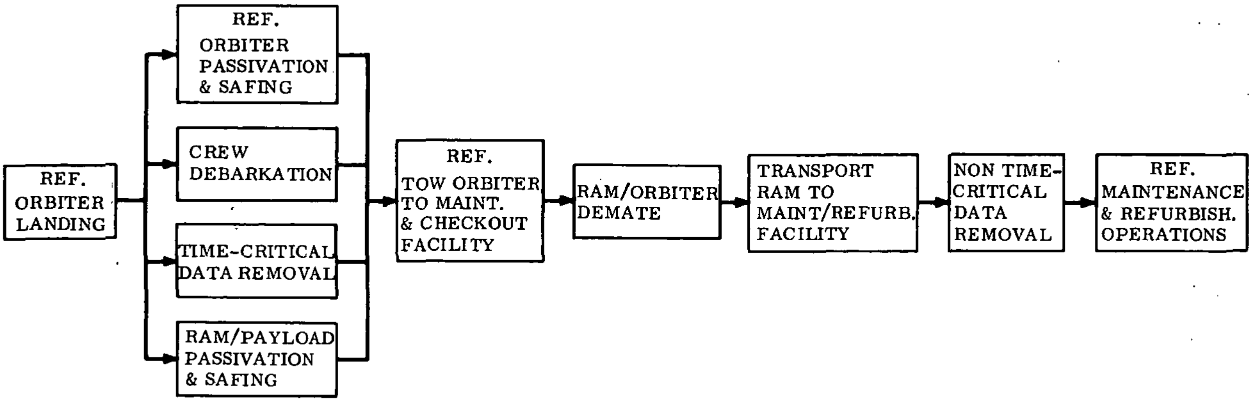


Figure 5-11. Typical Postflight Operations Flow (see Figure 5-7)

5.2.5 MAINTENANCE AND REFURBISHMENT OPERATIONS. A typical functional flow for maintenance and refurbishment operations is shown in Figure 5-12. After completion of postflight operations and any necessary calibrations and integrated checkout, RAM elements are demated as appropriate. RSMs will be demated from RAM payload modules, and RAM pallets may be demated from sortie RAMs or RAM payload modules that are to carry different payloads on their next mission. Maintenance and refurbishment activities are accomplished next in the most appropriate order for the specific case. These include removal of payload and payload integration equipment not required for the next mission, scheduled and unscheduled maintenance on the RAM payload carrier and payload, and updating of equipment as required.

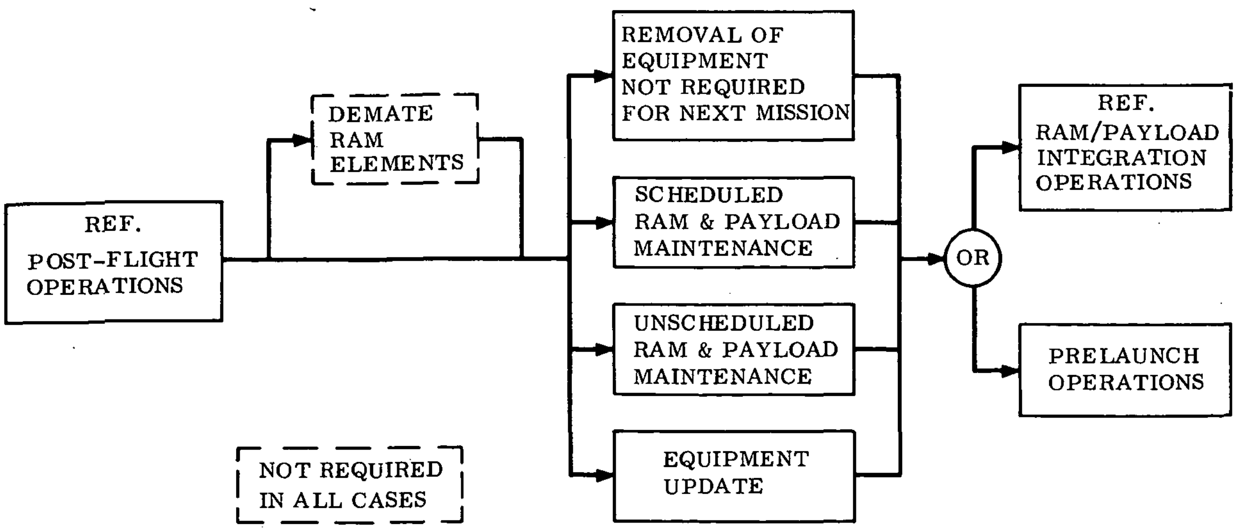


Figure 5-12. Typical Maintenance and Refurbishment Operations Flow (see Figure 5-7)

The flow shown in Figure 5-12 is most representative of a sortie RAM. For free-flying RAMs and station-attached RAM payload modules, which have typically been on orbit for periods of years, all equipment down to the basic structure is removed, structural repairs made as required, and new or refurbished equipment installed in a sequence analogous to production final assembly. These RAM payload carriers are then subjected to a complete production acceptance test sequence.

5.3 PAYLOAD CREW OPERATIONS

The RAM system crew cadre consists of a number of trained individuals whose activity and participation vary widely over the many years of program operation. This cadre has experience and training in a wide range of technical and scientific disciplines and possess the necessary skills and capabilities to conduct all RAM payload carrier/payload operations, maintenance, and emergency repair or survival procedures. Payload crew responsibilities include:

a. Checkout, fault isolation, and redundancy management of onboard RAM payload carrier subsystems and experiments.

b. Maintenance, calibration, and repair of onboard RAM payload carrier subsystems and experiments and other equipment to the level of the maintenance concept.

c. Inventory and management of onboard consumables.

d. Monitoring and control of experiment activities, onboard data processing, and data reduction as required plus assignment of transmission priorities and modes subject to orbiter safety procedures.

e. Payload carrier safety, damage control, corrective action, and escape.

f. Command and control of the RAM element, including daily scheduling of operations; experiment and application activities; work, test, and recreation cycles; and the assignment of payload crew duties.

The prime function of the payload crew is to achieve the experiment objectives. To further these objectives, the payload crew is freed of routine operations to the greatest practical extent by using man-tended automatic support systems. As a design goal:

a. Sortie missions will be free of other than minimum maintenance or servicing by deferring action until after landing or by mission abort.

b. Extravehicular activity is required only for experiment objectives or for contingency situations where other solutions are not practicable.

c. Orbiter crewmen are not normally available to support experimental operations except for monitoring and controlling orbiter vehicle (including payload) health and safety.

Two categories of payload crewmen are required to conduct on-orbit operations.

a. Mission Specialist. Responsible for management of payload operations and the interfacing of payload and orbiter inflight operations. Trained in vehicle and payload subsystems, flight operations, and payload management. The crew may include more than one mission specialist.

b. Payload Specialist. Responsible for payload/instrument operations. Detailed knowledge of instruments, payload operations, requirements, objectives, and supporting equipment. The crew may include more than one payload specialist.

5.3.1 RAM OPERATIONS TASK. Crew duties relative to the division of responsibilities between the shuttle crew and the payload crew are shown for typical major operations in Table 5-3. The station crew is responsible for the operation of RAM payload equipment and any subsystems peculiar to the RAM payload module. This includes the responsibility for the station interface as well as integrating station operations with other RAM payload module or station activities.

Table 5-3. Crew Responsibilities

Operations	Payload Crew	Shuttle Crew
EVA (Experiments)	Accomplish EVA experiments, monitor biomedical data, monitor experiment performance, control of rescue (Teleoperator).	Monitor operation as required.
Manipulator Deployment	Monitor internal RAM payload carrier information	Perform RAM payload carrier deployment to docking port
Pivoted Deployment	Monitor internal RAM payload carrier information.	Perform RAM payload carrier deployment to erected position.
Shuttle Airlock	Control operations for experiment use.	Monitor configuration, control pressurization as required.
Subsatellites (Experiments)	Deploy, control operations, retrieve.	Retrieve if manipulators are used, monitor as required.
Docking for servicing free-flying RAM	Connect interfaces, control pressurization, monitor internal free-flying RAM information from ground station relay.	Perform docking operations, monitor safety of operations.

5.3.1.1 Sortie Mission Subsystem Operations. Payload carrier subsystem operations management encompasses the payload crew tasks associated with preparing the subsystems for operation during various mission phases, operating these systems, and maintaining subsystems status. Maximum use is made of man-tended automatic techniques. In general, payload crew time is required only for evaluation of information displayed on the control and display console to assess subsystem compatibility with mission plans. Daily and periodic requirements imposing demands on crew during shuttle-supported sortie missions are summarized in Table 5-4.

Table 5-4. Subsystem Operations and Maintenance (Sortie Missions)

Subsystem	Start-Up	Crew Duties	Crew Time
Guidance and Control (G&C) (when applicable)	On orbit	Verify completion of gyro spin-up	15 min (7 hr after launch)
		Transfer G&C control to RAM element	15 min
		Routine operation	(Function of experiment)
		Transfer G&C control	15 min
		CMG spin down	15 min (4.5 hr elapsed)
Electrical	Prelaunch	Fuel-cell load check, inverter and battery voltage checks.	
		Subsystem status check.	15 min/day
		Fuel-cell purge.	15 min/day
Environmental Control	Prelaunch	Subsystem status check	15 min/day
		LiOH canister replacement	15 min/day
Thermal	Prelaunch	Subsystem status check	20 min/day
Habitability	Post circularization	Stow flight seat restraints	~45 min
	Pre-entry	Stow loose equipment for entry	~20 min
		Install flight seats for entry	~45 min
Control and Displays	Prelaunch	Subsystem status check	~30 min/day
		RAM payload carrier checkout	~15 min
		Payload checkout	~15 min
Communication-Data Management	Prelaunch	Enable	~30 min/day

Housekeeping and sanitation activities include the payload crew requirements associated with food preparation and general cleaning of RAM/shuttle facilities. Nominal crew requirements are:

a. Clean-up Activity:

Initial on-orbit cleaning	30 minutes
Personal hygiene - clean, restock, recycle	12 min/day
Galley - clean equipment and restock	15 min/day
Collect/dispose of waste (3 to 6 times)	45 min/day

b. Food Preparation:

Secure food, unpackage, start oven	10 min/meal
Crew size 2 + 2 (3 meals - single-shift)	30 min/day
2 + 2 + 2 (3 meals - single-shift)	30 min/day
2 + 2 + 2 (6 meals - two shift)	60 min/day
2 + 2 + 4 (6 meals - two shift)	60 min/day

5.3.1.2 Free-Flying RAM Servicing Operations. The free-flying RAM servicing mission imposes unique demands and requirements on payload crew time and skills. Included among these are:

a. Sortie RAM deployment.

b. Free-Flying RAM docking.

c. Special payload and free-flying RAM servicing techniques such as replacement of instruments requiring intravehicular activity (IVA) and replacement of free-flying RAM and payload components using the shuttle manipulators.

The elapsed time requirement for sortie RAM deployment using the shuttle manipulators is about 180 minutes, assuming no off-nominal conditions. It is estimated that the pivoted deployment concept will nominally require about 75 minutes.

The basic concept for maintaining free-flying RAM subsystems is removal and replacement of failed or degraded units at periodic intervals in a shirtsleeve environment. A faulty unit will normally be removed, replaced by another unit, and returned to earth. Onboard repair is considered only where replacement of the failed unit is not feasible. This method of maintenance minimizes the skills and time required by the payload crews Components that would require EVA are planned for ground replacement. The subsystem maintenance tasks and checkout should be accomplished by the servicing payload crew in approximately one shift.

5.3.1.3 Payload Crew Sizes. The payload crew sizes have been broken down into three classes: early-mission or single-shift capability, and preferred later-mission or multiple-shift capability. The single-shift payload crew size is for those early sortie mission payloads using a sortie RAM for experimentation with a basic payload crew of 2. The minimum multiple-shift payload crew size is required to effectively utilize the experiment facility. This crew size will not always use the entire facility capability, but represents a useful crew size that can conduct meaningful scientific results. The preferred multiple-shift crew size can use facility capabilities fully. Payload crew size listings are shown in Table 6-1, along with other requirements for representative RAM payloads.

5.3.2 PAYLOAD CREW TRAINING. Payload crew personnel selection, the periods during which they are required, the cross-training or multiple disciplines needed, the depth of training, the training lead time, and the physical preconditioning of crew members are based on 1) the RAM payload flight schedule, 2) the degree of payload automation, and 3) the shuttle system available for crew transport (i.e., low, medium, or high boost and entry g forces). With lower g forces, the number of individuals capable of functioning in space is broadened, permitting selection of many highly specialized scientists who might otherwise be ineligible.

Payload crew members may be astronauts with multidiscipline backgrounds or scientific community personnel with minimum space and RAM system knowledge, skills, and physical preconditioning. In general, scientific community personnel must have at least the skills and knowledge of RAM payload carrier to survive (alone if necessary) with minimum subsystem management and operations for the period required for the shuttle to return to earth.

5.3.2.1 Payload Crew Requirements. Major payload crew training requirements derived for the Reference Experiment Plan (REP) and the RAM elements are discussed in this section. Over the program life from 1980 to 1990, 386 man-missions are required to support the free-flying RAM, sortie RAM, and RSM/RAM payload module missions. As shown in Figure 5-13, a total complement of 54 (consisting of 15 mission specialists and 39 payload specialists) is required to support the RAM program. Peak payload crew loading, occurring in 1989, requires a maximum of 22 payload crewmen.

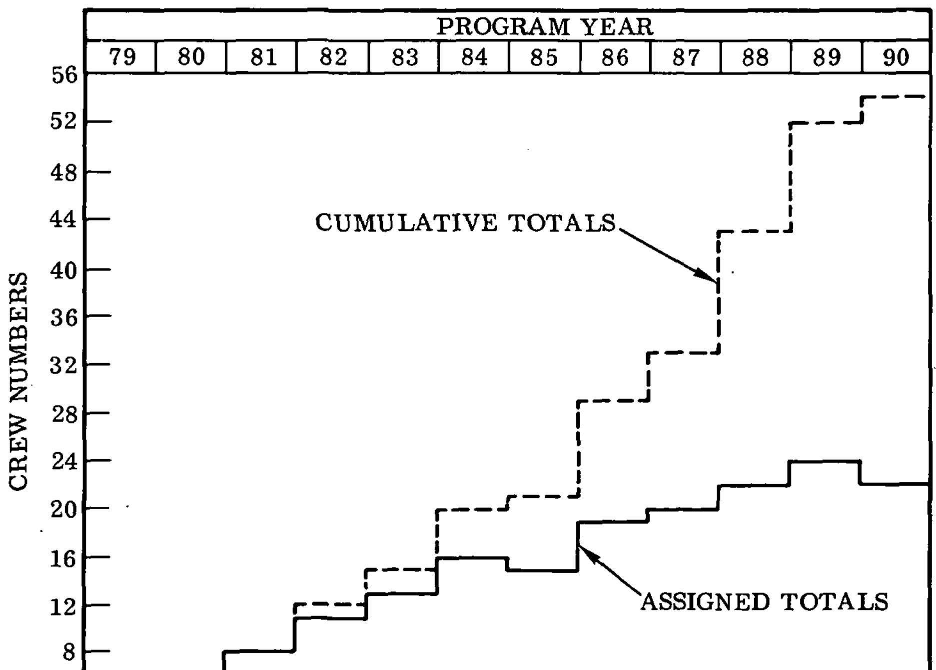


Figure 5-13. Crew Population Buildup

Payload crews receive a scheduled initial training course and recurrent training fcr subsequent missions. Typical initial training courses are shown in Table 5-5, which lists course areas, classroom briefing hours, and training article hours. Recurrent training consists of a six- to eight-week training period involving about 270 hours of training. Training equipment rather than classroom briefings is used primarily during recurrent training. A total of 126,000 scheduled crew training hours is required to implement the REP selected for analysis.

Table 5-5. Payload Crew Training Courses

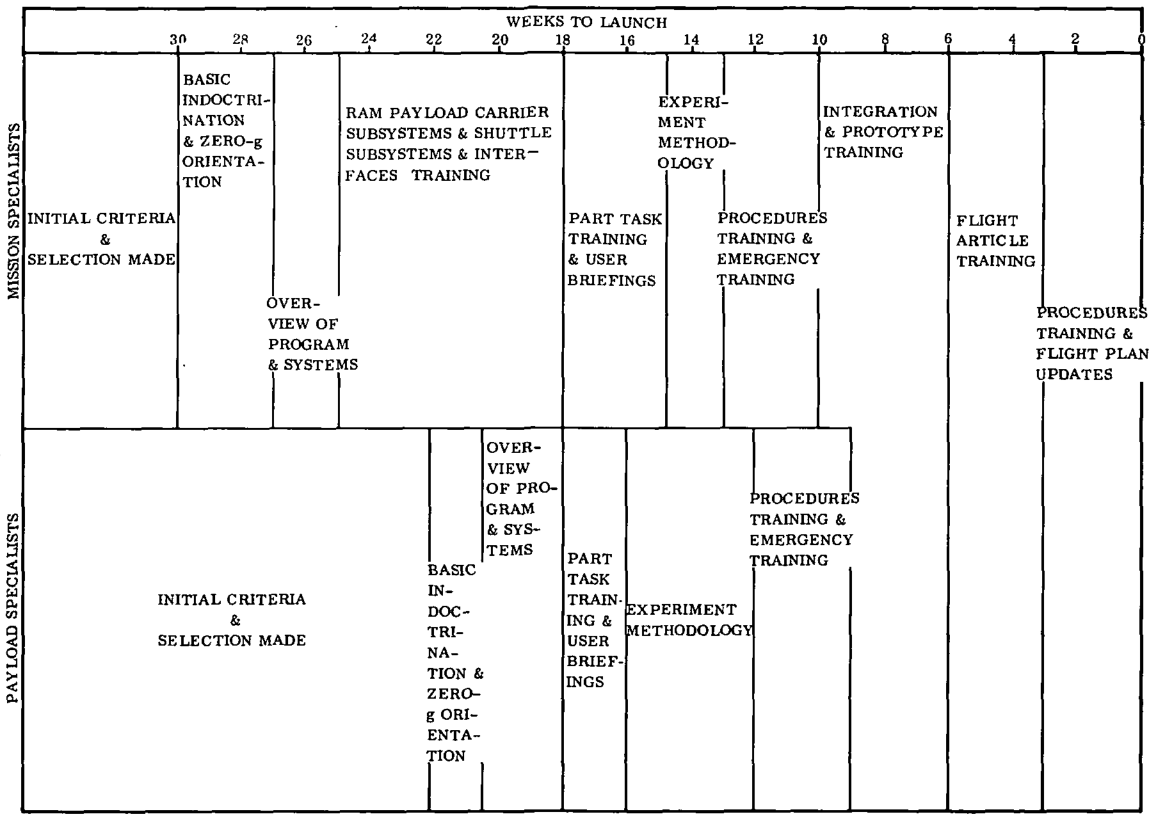
Course Area	Mission Specialist Hours				Payload Specialist Hours			
	Classroom Briefings	Trainers/ Mockups	Integration/ Flight Article	Totals	Classroom Briefings	Trainers/ Mockups	Integration/ Flight Article	Totals
Environment Adaption (neutral buoyance, centrifuge, pressure suits, etc.)	15		70	85	5		24	29
RAM Payload Carrier Overviews	10			10	20	30		50
Shuttle Overview and User Briefing	15	20		35	15	20		35
Experiments Overviews	10			10	10			10
Environmental Control and Life Support User Briefings	20	10	20	50	20	10	20	50
Data Management/Communications/ Controls and Displays User Briefings	30		30	60	30		70	100
Experiment Methodology	20 (See Note)		30	50	10		200	210
Electrical Power Subsystem Technology	15	21		36				
Data Management/Communications/ Controls and Displays/Checkout Technology	30	30		60				
Environmental Control and Life-Support Technology	15	21		36				
Structure Technology	15	21		36				
Crew/Habitability Technology	8	10		18				
Reaction Control System Technology*	18			18				
Guidance and Navigation Technology	30	10	30	70				
Thermal Control Subsystem Technology	8	10		18				
Shuttle Interface Technology	8	10	20	38				
Part Task Operations	30	60		90				
Integration and Emergency Operations	20	15	45	80	20	15	15	50
System and Flight Plan Updates	15		25	40	15		25	40
Totals	332	238	270	840	145	75	354	574

Note: This presents a minimum. In some cases Mission Specialists may receive the equivalent to that shown for Payload Specialists.

* Free-Flying RAMs only

5.3.2.2 Training Approach. The mission specialist and the payload specialist training follows the general flow shown in Table 5-6. Training starts with a basic indoctrination into the new environment and undertakes neutral buoyancy and Keplarian-trajectory aircraft flight training for zero-g problems and pressure suit familiarization. RAM program system/operations overviews and detailed classroom briefings on RAM payload carrier subsystems and shuttle subsystems interfaces are supplemented with classroom instructional aids. The payload crew trains with part-task trainers and RAM payload carrier/shuttle interface mockups. Experiment training consists of classroom briefings, prototype equipment, and procedures trainer mockups. During the integrated portion of the training flow, mission and payload specialists are trained as a team in the use of RAM payload carrier subsystems, experiment prototypes, mockups, and the actual flight articles. Costly training equipment such as mission simulators are not required; prototype equipment and actual RAM payload carrier subsystems are used and supplemented where required by GSE.

Table 5-6. Initial Course Training Flow



The training approach provides for cross-training directly between the specialists. The payload specialist provides most of the training of the mission specialist as his experiment assistant by working out procedures and instructing the mission

specialist in these procedures. Conversely, the mission specialist provides instruction to the payload specialist in subsystem interfaces with experiments and general zero-g operations. This training approach minimizes payload specialist training since the mission specialist assists the payload specialists during mission operations to maximize scientific return and minimize the effects of the zero-g environment on the payload specialists.

RESEARCH AND APPLICATIONS MODULES (RAM)
PHASE B STUDY

SECTION 6

PAYLOAD INTEGRATION

Prepared by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
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SECTION 6

PAYLOAD INTEGRATION

Technical requirements for the integration of payloads with RAM elements are covered in this section. Development of requirements for payload integration included analyses of payloads or experiments to define the unique requirements arising from equipment configuration or operational characteristics, operating environment, or supporting resources. Based on these requirements, design concepts were developed for payload integration equipment.

6.1 PAYLOADS ANALYSIS

6.1.1 PAYLOAD DISCIPLINE DEFINITION. The experiment catalog summarized in the "Reference Earth Orbital Research and Applications Investigations" (Blue Book) was developed with the specific intention of describing the facility and support requirements of experiment groups in seven disciplines: 1) Astronomy, 2) Physics, 3) Earth Observations, 4) Communications/Navigation, 5) Materials Science, 6) Technology, and 7) Life Sciences. Descriptions of these disciplines are included in the following paragraphs.

6.1.1.1 Astronomy. The Astronomy discipline consists of seven functional program elements (FPEs), i.e., groups of experiments characterized by mutually supportive experiments or experiments that impose similar resource demands. These experiments are: X-ray stellar astronomy, advanced stellar astronomy, advanced solar astronomy, and radio astronomy. The objective of space-based astronomy is to gain a better understanding of the universe (past, present and future) through remote sensing of celestial objects and events.

6.1.1.2 Physics. The Physics discipline will provide a capability to: 1) investigate chemical and energy conversion processes, evaluate the plausibility of photolysis as the causative mechanism of cometary spectra, and provide information on the trajectories of meteoroids, as well as their mass, velocity, and composition; 2) study plasma wakes, plasma resonances, wake particle interactions with VLF, and electron/ion beam propagation; 3) search for theoretically-predicted elementary particles (e.g., quarks, magnetic monopoles), and antimatter stars; and 4) conduct experiments in the unique environment of zero-gravity, high vacuum conditions with no wall effects, and free molecular flow regime.

6.1.1.3 Earth Observations. The Earth Observations discipline will use the unique capabilities of man in the orbital survey of the earth and its environment. Objectives of earth observation measurements are: 1) defining the earth's geometry; 2) understanding the physics of the atmosphere, the prediction of weather, and the establishment of a basis for weather modification and climate control; and 3) responsible management of the earth's resources and the human environment.

6.1.1.4 Communications/Navigation. The Communications/Navigation disciplines will facilitate continued and expanded application of space technology and satellite systems to better serve the national and international need for communications with and between earthbound, airborne, and spaceborne terminals, and to continually improve the capabilities for terrestrial, air, and space vehicle navigation and traffic control.

6.1.1.5 Materials Science. The purpose of the Materials Science discipline is to: 1) accomplish a wide variety of research experiments leading to a capability to manufacture materials in space or improve processes on earth; 2) conduct space experimentation to define specific prospects for manufacturing in space; and 3) to develop specific processes to the point of commercial feasibility for manufacturing in space.

6.1.1.6 Technology. The purpose of the Technology discipline is to: 1) monitor and trace the movement of external contaminants and evaluate techniques for removing or reducing the contaminates deposited, 2) understand the fundamentals and optimization of design practices for advanced spacecraft fluid systems, 3) investigate extravehicular activity using the astronaut maneuvering unit and maneuvering work platform, 4) provide the means to conduct experiments to insure that advanced components and systems will function properly when integrated into future operational spacecraft, and 5) provide a means for teleoperator system performance evaluation.

6.1.1.7 Life Sciences. The Life Sciences program encompasses operational and medical questions associated with: 1) manning and operating earth-orbital research facilities; 2) developing, testing, and incorporating into such facilities the advanced technology for life support and protective systems; and 3) fundamental biological and biomedical research.

6.1.2 REFERENCE PAYLOADS. Early in the study, a set of representative RAM payloads was defined by the study team with NASA concurrence and direction. Payload goals, objectives, operations, environments, equipment, and data inputs were then analyzed in detail to establish payload capabilities and to define derived requirements placed by the payloads on interfacing systems. Operational characteristics of the previously defined mission modes were then compared with the requirements for each payload to determine the mission modes that best meet payload requirements.

Requirements for representative RAM payloads have been identified and are summarized in Table 6-1. The payload data is divided into the following categories.

a. Physical — Total weight and volume, internal weight and volume.

b. Mission — Orbit, orientation, pointing, viewing constraint, pointing accuracy and stability, and pointing accuracy duration.

c. Resources — Crew, power, and data.

d. Environment — Acceleration, contamination, radiation, and temperature.

Table 6-1. Representative RAM Payload Summary Data

Payload Class	Discipline	Reference P/L No.	Reference Payload Title	Experiment Equipment – Physical: Total Weight (lb)	Total Volume (ft³)	Internal Weight (lb)	Internal Volume (ft³)	Mission: Orbit Preferred	Orbit Acceptable	Orbit Recommended	Orientation	Viewing Constraint	Pointing Accuracy; Stability	Point Duration (hr/obs)	Resources: Crew Size# Initial	Crew Size Advanced Minimum	Crew Size Advanced Preferred	Skills	Crew hr/day# Initial	Crew hr/day Advanced Minimum	Crew hr/day Advanced Preferred	Power (W)# Avg (on) Initial	Power Avg (on) Advanced	Power Peak	Peak Power Duration (hr)	Elect. Energy# (kW-hr/day) Initial	Elect. Energy Advanced	Data: Other Than Digital	Digital Rate (bps)	Environment: Accel. (g)	Contam.	Radiation (rad/hr)	Temp (°K)	Special
Sortie	Astronomy	A3S1B	Austere Solar Astronomy (Telescope)	4,920	180	714	28	Sun sync, 200 n. mi.	Any within rad limits	97 deg 220 n. mi.	Solar	Sunline > 170 km from horizon	10 arc-sec; 0.5-1.0 arc-sec/obs	0.01-0.8	2†	4	4	Astronomer/Astrophysicist	24	48	48	430	430	550Δ	0.1	6	11	Film, TV, H-α film	7M**	$<10^{-3}$	Particles gases	$<10^{-3}$	281-284	
		A6S1B	Austere IR Astronomy (ARC Telescope)	9,948	918	2,710	205	28-55 deg, 270 n. mi.	0-55 deg, 200-400 n. mi.	40 deg 300 n. mi.	Stellar	>45 deg from Sun ≥30 deg from Earth	1.0 arc-sec; 0.5 arc-sec/obs	0.1-5	2	4	4	Astronomer/Astrophysicist	24	48	48	1100	1100	835Δ	0.4	31.2	31.2	TV	7M**	$<10^{-3}$	Particles gases	$<10^{-3}$	233-313	
		A8S1U	Combined Austere Astronomy (ARC Telescope & High Energy Array)	12,411	1,313	3,194	266	28-55 deg, 270 n. mi.	0-55 deg, 200-400 n. mi.	40 deg 300 n. mi.	Stellar	>45 deg from Sun ≥30 deg from Earth	1 arc-sec; 0.5 arc-sec/obs	0.1-5	2	4	4	Astronomer/Astrophysicist	24	48	48	1465	1465	1220Δ	0.1	37.9	37.9	TV	7M**	$<10^{-3}$	Particles gases	$<10^{-3}$	288-293 233-313	
		A8S1V	Combined Austere Astronomy (Solar Telescope & High Energy Array)	8,357	894	1,319	88	Sun sync, 200 n. mi.	Any within rad limits	97 deg 250 n. mi.	Solar, stellar	Sunline >170 km from horizon	10 arc-sec; 0.5-1.0 arc-sec/obs	0.01-0.8	2†	4	4	Astronomer/Astrophysicist	24	48	48	800	800	500Δ	0.1	14	26.7	Film, TV	7M**	$<10^{-4}$	Particles gases	$<10^{-3}$	281-284 253-293	
		A8S1W	Combined Austere Astronomy (UV Wide Field Telescope & High Energy Array)	6,870	596	1,273	146	<55 deg, >300 n. mi.	<55 deg, >200 n. mi.	40 deg 300 n. mi.	Stellar	≥60 deg from Sun ≥15 deg to horizon	5-60 arc-sec; 1 arc-sec/obs	1 sec-1 hr	2†	4	4	Astronomer/Astrophysicist	24	48	48	1045	1045	540Δ	0.1	13	25.8	Film, TV	7M**	$<10^{-4}$	Particles gases	$<10^{-3}$	289-291 273-300	
		A8S1X	Combined Austere Astronomy (UV Narrow Telescope & High Energy Array)	8,832	1,153	1,497	153	<5 deg, 400-500 n. mi.	<55 deg, 200-400 n. mi.	40 deg 300 n. mi.	Stellar	≥60 deg to Sun ≥25 deg to horizon	1 arc-sec; 1.0 arc-sec/obs	0.2-0.8	2†	4	4	Astronomer/Astrophysicist	24	48	48	905	905	1050Δ	0.1	12	23.2	Film, TV	7M**	$<10^{-4}$	Particles gases	$<10^{-3}$	288-290 250-293	
		A8S1Z	Combined Austere Astronomy (IR Telescope & High Energy Array)	9,247	1,270	1,658	158	0 deg, 200-400 n. mi.	0-55 deg, 200-400 n. mi.	40 deg 300 n. mi.	Stellar	>90 deg from Sun >60 deg from Earth	1 arc-sec; 1 arc-sec/obs	≤0.75	2	4	4	Astronomer/Astrophysicist	24	48	48	867	867	575Δ	0.1	21.4	21.4	TV	7M**	$<10^{-3}$	Particles gases	$<10^{-3}$	253-293 233-313	
		A9S1J	Combined Austere Astronomy (Solar Telescope & High Energy Array)	9,865	1,301	1,721	146	<10 deg, 400 n. mi.	45-55 deg, 270 n. mi.	40 deg 300 n. mi.	Solar	On solar disc >22 deg from horizon	10 arc-sec; 2.5 arc-sec/obs	≤0.75	2	4	4	Astronomer/Astrophysicist	24	48	48	1041	1041	720Δ	0.1	26.2	26.2	TV	8.3M**	$<10^{-3}$	Particles gases	$<10^{-3}$	281-284 272-274	
	Physics	P5S1B	Combined Space/Plasma Physics (Austere)	4,373	189	4,162	187	Polar, 100 n. mi.	>50 deg, >100 n. mi.		Earth	None	120 arc-sec; 12 arc-sec/sec	96 continuous	2	4	4	Optical/Electromechanical, Physicist/Nuclear Physicist	24	48	48	1800	2100	900Δ	6	44	50	—	11M	—	Sensitive	—	—	Airlock & Booms
		P5S2A	Combined Space/Plasma Physics (Intermediate)	5,185	239	5,118	239	Polar, 100 n. mi.	>50 deg, >100 n. mi.		Stellar & Earth	Dark	1.6 arc-sec; 0.5 arc-sec/sec	1	2	4	5	Optical/Electromechanical, Physicist/Nuclear Physicist	24	48	60	1500	1500	400Δ	2	24	36	—	11M	—	Sensitive	—	—	Airlock & Booms
		P7S1A	Combined Cosmic Ray Physics & Chemistry (Austere)	2,841	229	2,316	221	28.5 deg <200 n. mi.	Any		Earth	None	1.0 deg; 0.1 deg/sec	10	2	4	4	Physicist, Phys. Chemist, Optical/Electromechanical	24	48	48	2200	2200	—	—	22	44	Film	40k	—	—	—	—	Airlock & Boom
		P7S3A	Combined Cosmic Ray Physics & Chemistry (Advanced)	13,448	759	5,819	439	<300 n. mi.	Any		Earth	None	1.0 deg; 0.1 deg/sec	10	2	4	4	Optical/Electromechanical, Physicist/Nuclear Physicist	24	48	48	2000	2200	2100Δ	4	30	53	TV, Film	50k	$<10^{-4}$	gases	—	—	Airlock & Boom
		P8S2B	Combined Space Plasma/Cosmic Ray Physics (Intermediate)	8,003	335	7,160	294	Polar, 100 n. mi.	>50 deg, >100 n. mi.		Earth	None	±120 arc-sec 12 arc-sec/sec	96 continuous	2	4	6	Optical/Electromechanical, Physicist/Nuclear Physicist	24	48	72	1900	2000	1000Δ	6	32	48	—	11M	—	Sensitive	—	—	Airlock & Boom
	Earth Observations	E1S1N	Earth Observation (Weather) - Austere	4,462	686	2,376	125	Polar, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.01 deg/sec	15 min/obs	2	4	4	Meteorologist, Tech's, Oceanographer	13.8	28	28	3400	3400	900Δ	0.5/day	7.9	15.8	Film	125k	$<10^{-5}$	Sensitive	—	—	
		E1S1O	Earth Observation (World Land Use Mapping) - Austere	4,789	397	3,077	107	Polar, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.05 deg/sec	25 min/obs	2	4	4	Photo Tech/Cartographer, Geographer, Geologist, Tech	16	32	32	4800	4800	900Δ	0.9/day	14.7	29.4	Film	50.1M	—	Sensitive	—	—	
		E1S1P	Earth Observation (Air & Water Polution) - Austere	3,598	331	2,613	99	50 deg, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.05 deg/sec	12 min/obs	2	4	4	Meteorologist, Oceanographer, Hydrologist, Tech's	17.6	36	36	3000	3000	800Δ	~milli-secs	9.8	19.6	Film	51.3M	—	Sensitive	—	—	
		E1S1Q	Earth Observation (Resource Location) - Austere	4,722	392	2,987	105	Polar, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.05 deg/sec	15 min/obs	2	4	4	Geographer, Agronomer, Optical, Photo Tech	16.8	34	34	4800	4800	900Δ	0.75/day	11.2	22.4	Film	50M	—	Sensitive	—	—	
		E1S1R	Earth Observation (Disaster Assessment) - Austere	4,217	383	2,740	103	70 deg, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.05 deg/sec	3 min/obs	2	4	4	Meteorologist, Geologist, Agronomist, Tech	13.8	28	28	2600	2600	2800Δ	3-6 min/day	5.1	10.2	Film	51.4M (800M growth)	—	Sensitive	—	—	1.8×10^9 bits/day near R. T.
		E1S1S	Earth Observation (Ocean Resources) - Austere	2,918	524	1,710	83	Polar, 100 n. mi.	50 deg		Earth	±60 deg from nadir*	±0.5 deg; 0.05 deg/sec	15 min/obs	2	4	4	Meteorologist, Oceanographer, Optical/Electromechanical	14.6	30	30	2600	2600	500Δ	~milli-secs	7.7	15.4	Film	51.3M	—	Sensitive	—	—	
	COM/NAV	C1S1E	Communication/Navigation (Lab I) - Austere	1,708	116	970	49	Polar	28 deg-polar		Earth	180 deg	0.01 deg; 1 deg/sec	15 min/obs	2	4	4	Electronics/Microwave, Optical/Electromechanical	24	48	48	1100	1100	800Δ	1.5	14.5	22	Real time digital stor	0.8M	—	Sensitive	—	—	300 kbps R. T. Trans
		C1S1F	Communication/Navigation (Lab I) - Austere	1,489	120	849	42	Polar	28 deg-polar		Earth	180 deg	0.01 deg; 0.1 deg/sec	15 min/obs	2	4	4	Electronic/Eng/Microwave	24	48	48	1250	1250	550Δ	1.5	16	25	Real time digital stor	0.3M	—	—	—	—	30 kbps R.T. Trans
		C1S2C	Communication/Navigation (Lab II) - Intermediate	3,875	239	1,657	83	Polar	28 deg-polar		Earth, stellar, entry	180 deg	0.01 deg; 0.1 deg/sec	60 min/obs	2	4	4	Electronics, Optics, Microwave, Electromech	24	48	48	1500	1500	1000Δ	1.5	16	25	Real time digital stor	1.3M	—	Sensitive	—	—	300 kbps R.T. Trans
	Materials Science	M1S1E	MS Configuration 1 - Operations Level 1	3,100	264	2,815	257	Any	Any		-	-	-	—	2	4	4	Electromechanical Technician,	24	48	48	0.1-1k		4-12k	1.5	18	28.6	TV	10k	$<10^{-4}$	—	—	—	
		M1S1F	MS Configuration 1 - Operations Level 2	3,100	264	2,815	257	Any	Any		-	-	-	—	2	4	4	Metallurgist, and	24	48	48	0.1-1k		4-12k	1.5	21	34.3	TV	10k	$<10^{-4}$	—	—	—	
		M1S1G	MS Configuration 1 - Operations Level 3	3,361	267	3,076	260	Any	Any		-	-	-	—	2	4	4	Chemical Technician	24	48	48	0.5-1.5k		4-30k	1.5	32	49	TV	10k	$<10^{-4}$	—	—	—	
		M1S2B	MS Configuration 2 - Operations Level 3	5,317	488	4,807	475	Any	Any		-	-	-	—	2	4	4	(for all 4 payloads)	24	48	48	0.5-1.5k		4-30k	1.5	32	49	TV	10k	$<10^{-4}$	—	—	—	
	Technology	T1S3A	Complete Contamination Measurements	660	40	499	29	Any	-		Sun Vector	-	0.5 deg; 0.05 deg/sec	14	1	2	2	Optical/Electromechanical, Physicist/Nuclear Physicist	2	4	8	825	825	360Δ	0.5	1.9	1.9	TV	107k	—	—	—	—	Piggyback
		T2S1A	Propellant Transfer Experiment	7,059	806	0	0	Any	-		-	-	-	—	2†	2	4	Electromechanical Tech	6	6	12	200	200	1000Δ	2	4.4	4.4	—	6.6k	Shuttle ambient	—	—	—	
		T2S2E	Combined Cryogenic Storage & Fluid Systems Experiment	19,530	2,241	7,140	132	Any	-		-	-	-	—	2†	2†	4	Electromechanical Tech	12	12	24	750	750	1800Δ	3 min	4.5	4.5	Film	1k	Shuttle ambient	—	—	—	
		T3S1A	Astronaut Maneuvering Unit Experiment	2,426	162	1,201	46	Any	-		Stable during EVA	Clear view of exp	-	—	3	4	6	Optical/Electromech Tech	31	43	65	330	330	40Δ	0.05	2.4	2.4	Film, TV	5k	—	—	—	—	EVA
		T3S2B	Maneuverable Work Platform Experiment	5,230	304	1,247	47	Any	-		Stable during launch, retrieval	Clear view of exp	-	—	3	4	4	Optical/Electromech Tech, Electronics/Microwave, M. E.	36	48	48	300	300	400Δ	0.25	9.2	9.2	TV	8k	—	—	—	—	EVA
		T4S1A	Short Duration Advanced Spacecraft Systems Test	1,000	50	1,000	50	Any	-		-	-	-	—	—	2	2	General skill	—	24	24	—	500	—	—	—	2.5	—	0.14M/day	—	—	—	—	Piggyback
		T5S2B	Teleoperator Experiment	1,952	139	1,450	135	Any	-		Stable during exp	-	-	—	2	4	4	Optical/Electromech Tech	20	40	48	160	160	140Δ	12	12.2	12.5	TV	40k	—	—	—	—	

* 30- to 60-degree sum elevation angle for UV & visible region sensing for Earth Observation payloads.
† Can be operated by one man/shift.
** Averaged over 1 sec; actual readout to buffer storage is 14×10^6 bps to allow 1/2 sec for exposure and 1/2 sec for readout. This value is for TV data; basic data rate is much lower.
\# Initial is for Early capability; Advanced is for Later capability.

Payload Class	Discipline	Reference P/L No.	Reference Payload Title	Experiment Equipment - Physical: Total Weight (lb)	Total Volume (ft^3)	Internal Weight (lb)	Internal Volume (ft^3)	Mission: Orbit Preferred	Orbit Acceptable	Orbit Recommended	Orientation	Viewing Constraint	Pointing Accuracy; Stability	Point Duration (hr/obs)
Sortie (Contd)	Life Science	L8S1B	Life Sciences Lab (Mini-7)	5,056	618	4,856	608	0 deg, 250 n. mi.***	Any		-	-	-	—
		L8S2B	Life Sciences Lab (Mini-30)	9,906	1,266	9,706	1,256	0 deg, 250 n. mi.***	Any		-	-	-	—
		L8(D)1A	Bioresearch Module	400	20	-	-	>200 n. mi.	>200 n. mi.		-	-	-	—
Free-Flying	Astronomy	A1O3B	X-Ray Astronomy Observatory	13,904	181	4,402	137	0 deg 400 n. mi.	0-5 & 28-55 deg 200-300 n. mi.	40 deg 300 n. mi.	Stellar	>45 deg from Sun >22 deg from Earth	1 arc-sec; 1 arc-sec/obs	≤9.5
		A2O2B	Large Space Telescope	12,846	2,854	2,136	654	28.5 deg 400 n. mi.	28-55 deg 250-350 n. mi.	40 deg 300 n. mi.	Stellar	≥45 deg to Sun ≥22 deg to Earth	1 arc-sec; 0.005 arc-sec/obs	0.3-6
		A2O3B	Advanced Stellar Astronomy Observatory	15,023	5,803	2,298	347	28.5 deg 400 n. mi.	28-55 deg 250=350 n. mi.	40 deg 300 n. mi.	Stellar	≥60 deg to Sun ≥22 deg to Earth	1 arc-sec 0.005 arc-sec/obs	0.3-6
		A3O3B	Advanced Solar Astronomy Observatory	9,934	2,193	6,285	1,513	<10 deg 400 n. mi.	0-5 & 28-55 deg 270-300 n. mi.	40 deg 300 n. mi.	Solar	0.3 deg of Sun center	1 arc-sec; 0.017 arc-sec/obs	≤0.75
		A5O2D	High Energy Stellar Astronomy Observatory	3,205	185	1,549	122	0 deg 400-500 n. mi.	0-5 & 28-55 deg 200-300 n. mi.	40 deg 300 n. mi.	Stellar	≥60 deg to Sun ≥22 deg to Earth	2 arc-sec; 1 arc-sec/obs	0.1-6
		A5O3B	High Energy Stellar Astronomy Observatory	8,883	772	3,466	400	0 deg 400-500 n. mi.	0-5 & 28-55 deg 200-300 n. mi.	40 deg 300 n. mi.	Stellar	≥60 deg to Sun	2 arc-sec/obs	0.1-6
		A7O3A	Large Radio Astronomy Observatory	10,933	3,332	1,613	287	28-55 deg 350 n. mi.	28-55 deg 270-400 n. mi.	40 deg 300 n. mi.	Stellar & Solar	≥15 deg from earth horizon	1 arc-sec 1 arc-sec/obs	0.75
	Technology	T1O3B	Complete Contamination Measurement	145	9	101	6	Any	-		-	-	-	—
		T2(D)2B	Detached Long-Term Cryogenic Storage Equipment	7,470	1,323	-	-	Sun Sync	Any		Inertial & Earth	-	-	—
		T4O1A	Long Duration Advanced Spacecraft Systems Test	1,000	50	-	-	Any	-		-	-	-	—
Station-Attached	Astronomy	A4A2A	Narrow Field UV Astronomy	3,760	436	928	93	28-55 deg 400 n. mi.	28-55 deg 200-400 n. mi.	55 deg 270 n. mi.	Stellar	≥60 deg to Sun ≥25 deg to Earth	1 arc-sec 1 arc-sec/obs	0.2-0.8
		A6A3A	Austere Astronomy (IR Telescope)	5,369	487	917	90	50-60 deg 270-300 n. mi.	25-70 deg 250-400 n. mi.	55 deg 270 n. mi.	Stellar	>90 deg to Sun >60 deg to Earth	1 arc-sec 1 arc-sec/obs	0.75
	Physics	P3A3A	Cosmic Ray Laboratory	34,954	763	34,634	741	28 deg, 200 n. mi.	55 deg, 270 n. mi.		Away from Earth	No data if viewing Earth	1 deg knowledge; ±45 deg/obs	Essentially continuous
		P6A3A-1	Combined Space/Plasma Physics Laboratory (Complete)	9,961	506	7,516	416	Polar 100 n. mi.	>50 deg >100 n. mi.		Earth & Stellar	Dark	1.6 arc-sec 0.5 arc-sec/sec	Continuous
		P6A3A-2	Physics and Chemistry Laboratory (Complete)	5,972	422	5,874	422	<300 n. mi.	Any		Earth	None	1.0 deg; 0.1 deg/sec	10
	Earth Observations	E1A2B	Intermediate Earth Observations Lab	5,760	432	3,973	142	55 deg, 270 n. mi.	50-90 deg, 100-270 n. mi.		Earth	±60 deg from nadir*	0.5 deg; 0.05 deg/sec	15 min/obs
		E1A3B	Complete Earth Observations Lab	7,853	1,018	4,446	182	55 deg, 270 n. mi.	50-90 deg 100-270 n. mi.		Earth	±60 deg from nadir*	0.5 deg; 0.01 deg/sec	25 min/obs
	COM/NAV	C1A2B	Communication/Navigation (Lab II) - Intermediate	4,492	278	2,469	130	Polar	28 deg, polar		Earth	360 deg	0.01 deg; 0.1 deg/sec	90 min/obs
		C1A3B	Communication/Navigation (Lab III) - Complete	4,932	344	2,568	136	Polar	28 deg, polar		Earth	360 deg	0.01 deg; 0.1 deg/sec.	90 min/obs
	Materials Science	M1A3B	MS Configuration 2 - Operations Level 4	5,356	492	4,946	579	Any	Any		-	-	—	—
	Technology	T1A3A	Complete Contamination Measurement	675	43	675	43	Any	-		Solar	-	0.5 deg; 0.05 deg/sec	14
		T4A1A	Medium Duration Advanced Spacecraft Systems Test	1,000	50	1,000	50	Any	-		-	-		—
	Life Sciences	L8A1B-1	Station Mission (Midi 30, F Module)	11,621	1,967	11,621	1,967	0 deg 250 n. mi. ***	Any		-	-	-	—
		L8A1B-2	Station Mission (Midi 30, BLH Module)	4,773	652	4,573	642	0 deg, 250 n. mi.***	Any		-	-	-	—
		L8A2B-1	Station Mission (Maxi Nom, F Module)	14,232	2,156	14,232	2,156	0 deg, 250 n. mi. ***	Any		-	-	-	—
		L8A2B-2	Station Mission (Maxi Nom, BLH Module)	5,171	678	4,971	668	0 deg, 250 n. mi. ***	Any		-	-	-	—

Reference P/L No.	Resources: Crew Size # Initial	Crew Size Advanced Minimum	Crew Size Advanced Preferred	Skills	Crew hr/day # Initial	Crew hr/day Advanced Minimum	Crew hr/day Advanced Preferred	Power (W)# Avg (on) Initial	Power Avg (on) Advanced	Power Peak	Peak Power Duration (hr)	Elect. Energy# (kW-hr/day) Initial	Elect. Energy Advanced	Data Other Than Digital	Data Digital Rate (bps)	Environment: Accel. (g)	Contam.	Radiation (rad/hr)	Temp (°K)	Special
L8S1B	3	4	6	Biol Tech, M.D., Electromech Tech, Behavioral Sci.	36	48	72	3300	3300	NS	NS	42	48	TV Std + High Res. TV	300	$\leq 10^{-5}$, 95% of time	—	Minimum	—	EVA; dump 10%/day rec. data
L8S2B	3	4	6	Biol Tech, M.D., Electromech Tech, Behavioral Sci.	30	40	60	3300	3300	NS	NS	48	50.2	TV Std + High Res. TV	500	$\leq 10^{-5}$, 95% of time	—	Minimum	—	
L8(D)1A	—	1	1	Electromech Tech	—	NS	NS	—	90-150	—	—	NS	NS	—	2000	$<10^{-4}$	—	Minimum	—	Piggyback
A1O3B	2‡	2‡	2‡	Astronomer/Astrophysicist	18	18	18	1240	1240	310Δ	0.1	30.2	30.2	TV	120M	$<10^{-4}$	Particles gases	$<10^{-3}$	272-274	
A2O2B	2‡	2‡	2‡	Optical Scientist/Technician	24	24	24	1000	1000	180Δ	0.8	26.2	26.2	Digital camera, TV	5M	$<10^{-4}$	Particles gases	$<10^{-3}$	273-275	
A2O3B	2‡	2‡	2‡	Optical Scientist/Technician	24	24	24	1500	1500	150Δ	0.1	32	32	TV	175M	$<10^{-4}$	Particles gases	$<10^{-3}$	273-275	
A3O3B	2‡	2‡	2‡	Astronomer/Astrophysicist	24	24	24	2180	2180	450Δ	0.06	52.3	52.3	TV	1236M	$<10^{-4}$	Particles gases	$<10^{-3}$	290-297	
A5O2D	2‡	2‡	2‡	Astronomer/Technician	16	16	16	750	750	600Δ	0.1	18.9	18.9	TV	120M	$<10^{-4}$	Particles gases	$<10^{-3}$	273-277	
A5O3B	2‡	2‡	2‡	Astronomer/Technician	16	16	16	1486	486	314Δ	0.5	12.1	12.1	TV	120M	$<10^{-4}$	Particles gases	$<10^{-3}$	272-277	
A7O3A	2‡	2‡	2‡	Astronomer/Optical/Electromechanical Tech.	24	24	24	500	500	1500Δ	0.8	30	30	TV	7M	$<10^{-4}$	Particles gases	$<5 \times 10^{-3}$	292-294	
T1O3B	Neglig.	—	—	—	—	—	—	125	125	—	—	3.4	3.4	—	40.8k	—	—	—	—	Piggyback
T2(D)2B	Negligible	—	—	—	—	—	—	500	500	—	—	12.0	12.0	—	4.6k	Low-g coast	—	—	—	
T4O1A	Negligible	—	—	—	—	—	—	500	500	—	—	0.15	0.15	—	6 M/day	—	—	—	—	Piggyback
A4A2A	—	2	6	Astronomer/Technician	—	20	48	-	612	445Δ	0.1	15.4	15.4	TV	8M	$<10^{-4}$	Particles gases	$<10^{-3}$	288-290	
A6A3A	—	2	6	Astronomer/Technician	—	20	48	—	459	445Δ	0.1	11.7	11.7	TV	7M	$<10^{-3}$	Particles gases	$<10^{-3}$	272-274	
P3A3A	—	2	2	Physicist, Electromechanical Technician	—	5	5	—	690	160Δ	24 hr once/week	17-20	17-20	—	30k	—	Not critical	—	—	Thin windows
P6A3A-1	—	2	4	Physicist, Nuclear Physicist, Technician	—	20	40	—	2000	1000Δ	6	48	48	—	11M	$<10^{-4}$		—	—	Airlock & booms
P6A3A-2	—	2	4	Optical/Electromechanical, Physicist/Nuclear Physicist	—	20	40	—	2200	2100Δ	4	53	53	TV, Film	40k	$<10^{-4}$	Gases	—	—	Airlock & booms
E1A2B	—	4	4	Meteorol., Oceanog., Geol., Hydrol., Agron., Optical	—	28	40	—	4800	900Δ	10 min/day intermit.	26.2	26.2	Film	51.4M (800M growth)	—	Sensitive	—	—	1.8×10^9 bits/day near R.T.
E1A3B	—	4	4	Meteorol., Oceanog., Geol., Hydrol., Agron., Optical & Others	—	28	40	—	4800	900Δ	1/day intermit.	48.8	48.8	Film		$<10^{-5}$	Sensitive	—	—	
C1A2B	—	4	4	Optical/Electromech Tech Electronics/Microwave	—	40	40	—	1500	1000Δ	1.5	31.6	31.6	Real time digital stor	1.6M	—	Sensitive	—	—	30 kbps R.T. trans
C1A3B	—	4	4	Electronic, Electro-Optical, Microwave, Electro-Mech	—	40	40	—	1500	1000Δ	1.5	65.4	65.4	Real time digital stor	1.6M	—	Sensitive		—	1×10^6 kbps R.T. trans
M1A3B	—	4	4	Electromechanical Technician, Metallurgist, Chemical Tech., Photo Technician	—	40	40	—	500-2000	4-50k	1.5	21.3 nom.	21.3 nom.	TV	10k	$<10^{-4}$	—	—	—	
T1A3A	—	2	2	Physicist, Electromechanical Technician	—	8	12	-	825	360Δ	30 min	1.9	1.0	TV	107k	—	—	—	—	Piggyback
T4A1A	—	NS	NS	NS	—	NS	NS	—	500	—	—	2.5	2.5	—	33.4	—	NS	—	—	Piggyback
L8A1B-1	—	3	3	Biological Technician, Electromechanical Tech.	—	24	24	—	3823	—	—	72.5	72.5	TV Std + Hi Res. TV	8k	$\leq 10^{-5}$, 95% of time	—	Minimum	—	—
L8A1B-2	—	3	3	M.D., M.E., Behavioral Sci.	—	24	24	—	2000	—	—	22.8	22.8	Std. TV	16k	$\leq 10^{-3}$, 95% of time	—	Minimum	—	EVA
L8A2B-1	—	3	3	Biological Technician Electromechanical Tech.	—	24	24	—	3823	—	—	72.5	72.5	TV Std + Hi Res. TV	16k	$\leq 10^{-5}$, 95% of time	—	Minimum	—	—
L8A2B-2	—	3	3	M.D., M.E., Behavioral Sci.	—	24	24	—	2000	—	—	22.8	22.8	Std. TV	16k	$\leq 10^{-3}$, 95% of time	—	Minimum	—	EVA

* 30- to 60-degree Sun elevation angle for UV & visible region sensing for Earth Observations payloads.
† Can be operated by one man/shift.
\# Initial is for Early capability; Advanced is for Later capability.
‡ Free-flying module revisited for servicing.
*** Radiation consideration only.
NS = not specified

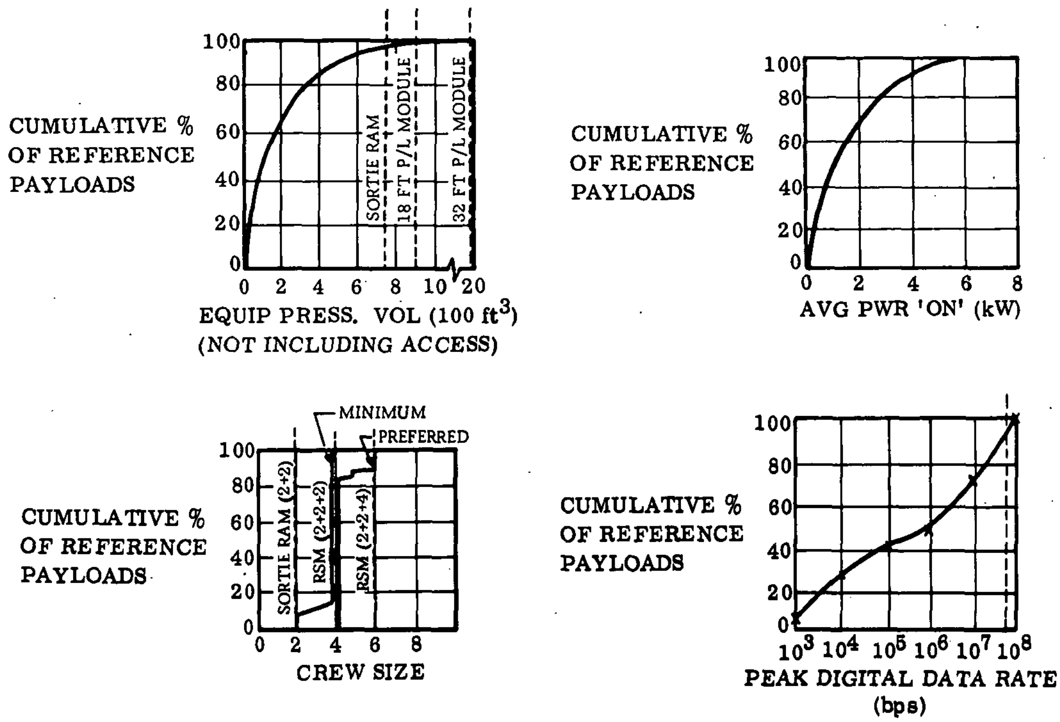
These payloads are not intended to imply any priority or specific endorsement, but are judged to adequately represent the broad spectrum of potential experiments in terms of physical limitations, common facilities, environment, orbits, and similar research demands. Analysis of this group of payloads has been particularly beneficial in establishing basic payload carrier subsystem capabilities for each RAM element. The RAM elements are not designed to specifically accommodate the reference payloads, but consideration was given to satisfying a maximum number of experiments while not generating an excess capability (beyond desired growth potential) that could impose serious weight and accommodation penalties.

Representative payloads identified for the RAM program were designated by the identification code presented in Table 6-2. As shown in the example at the top of the table, the payload designator code is composed of four parts. The first alphanumeric designation (a) is the functional program element or experiment group, the second designator (b) is the alpha designation for the mission mode (either sortie, observatory or attached to station), the third designator (c) is the time period (early, intermediate, or later missions), and the last designator (d) is the payload version designator (A through Z).

Table 6-2. Payload Designator Code

Item		(a) A8	(b) S	(c) 1	(d) Z	(Example)
(a)	Functional Program Element (FPE) or experiment group designation:					
	A1 - A6	Astronomy - Representative of Blue Book FPEs				
	A7 - A9	Astronomy - Additional Payloads				
	P1 - P4	Physics - Representative of Blue Book FPEs				
	P5 - P8	Physics - Combined FPEs				
	E1	Earth Observations				
	C1	Communications/Navigation				
	M1	Materials Science				
	T1 - T5	Technology				
	L8	Life Sciences - Combined FPEs (LS-1 to LS-7)				
(b)	Mission Mode:					
	S	Sortie				
	O	Observatory (Free Flying)				
	A	Attached to Station				
(c)	Payload Category:					
	1	Early Mission				
	2	Intermediate Capability Mission				
	3	Later or Advanced Mission				
(d)	Payload Version Designator A through Z					

Figures 6-1 through 6-3 summarize the range and distribution of important resource requirements for representative RAM payloads. These curves are examples of the techniques used to analyze payload requirements.



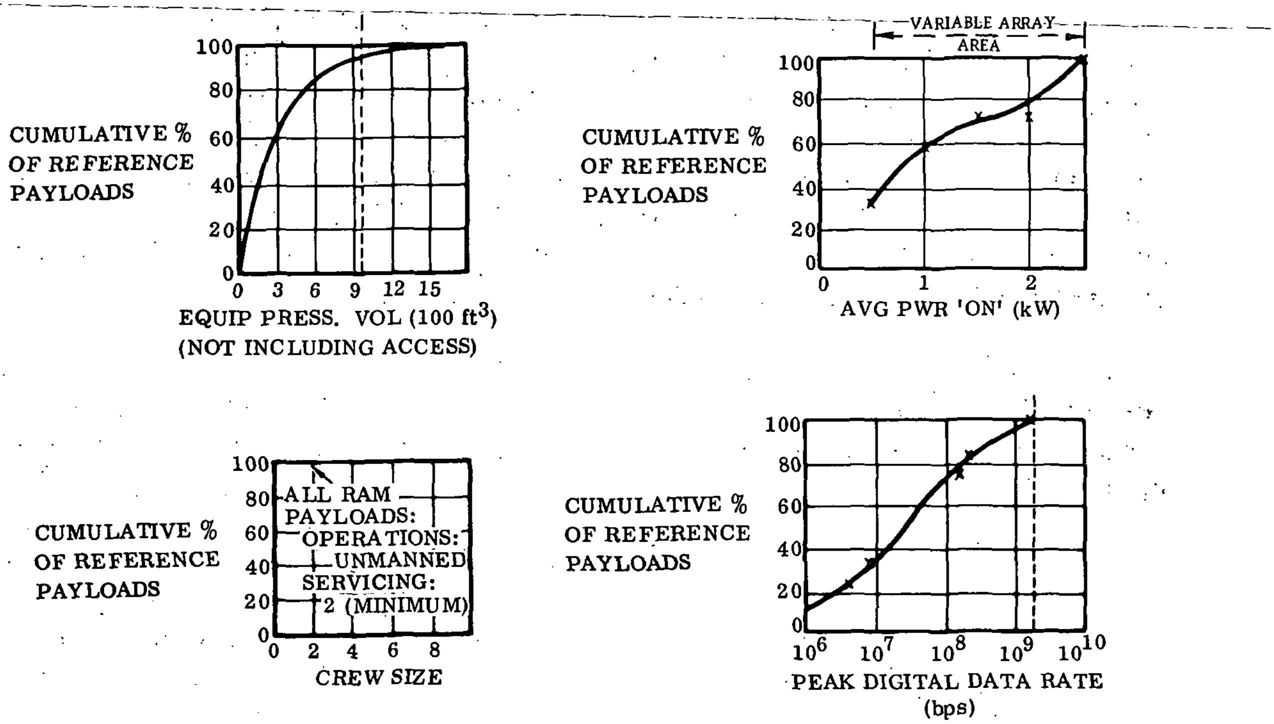
BASED ON 33 REPRESENTATIVE SORTIE MISSION PAYLOADS
— — — IMPLEMENTATION PROVIDED

Figure 6-1. Sortie Mission Payload Resources Requirements

6.1.3 PAYLOAD ENVIRONMENT

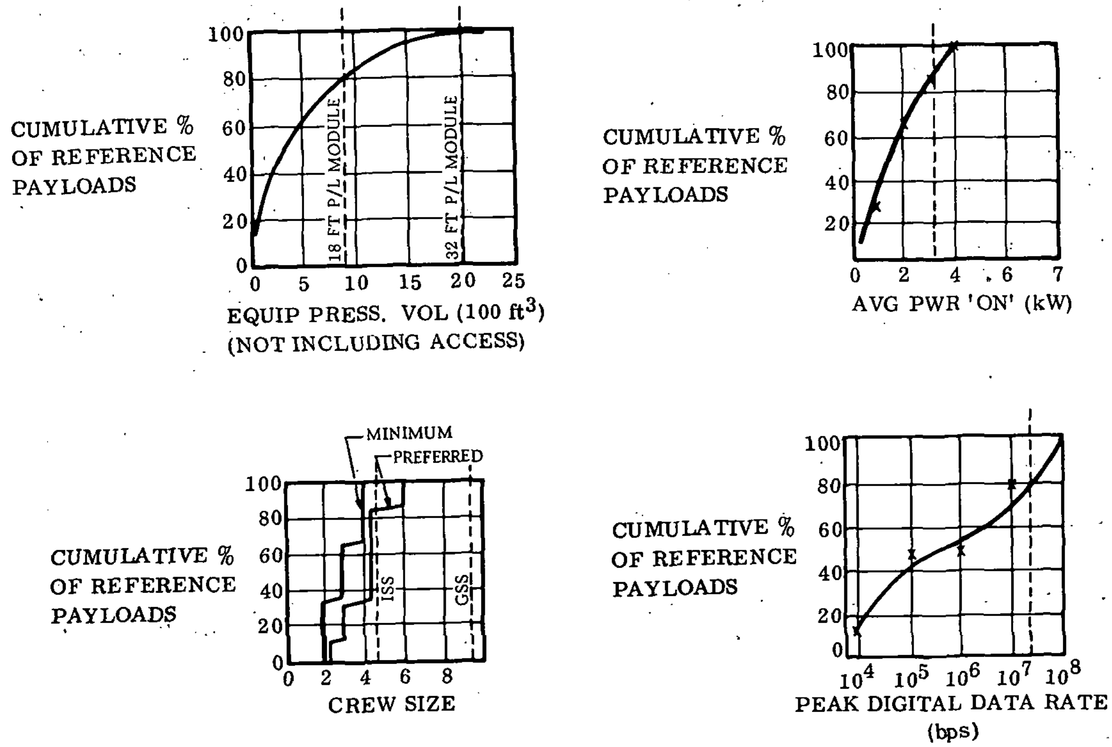
6.1.3.1 Thermal Control. The most demanding requirements for fine thermal control of the reference payload equipment are those of the Astronomy discipline. Since the basic RAM payload carrier thermal control system does not provide the fine control required for astronomy payload instruments, the function must be performed by auxiliary equipment.

Review of a number of alternative techniques for sortie astronomy missions led to the selection of an active control system based on ATM technology. The system employs a liquid heat sink that surrounds the instruments, except at the entrance aperture, and cools and heats the instruments by radiation. The heat sink is contained within an insulated thermal shield that isolates the contents from the external environment, except for heat transfer through the aperture when the cover is open. Liquid is circulated through the heat sink by a thermal interface unit, which exchanges heat with the RAM payload carrier thermal control system. Thermal control of the electronics for the telescopes, instruments, arrays and amplifiers will be by cold plates and/or convective cooling within the pressurized RAM.



BASED ON 8 REPRESENTATIVE FREE-FLYING RAM PAYLOADS
— — — IMPLEMENTATION PROVIDED

Figure 6-2. Free-Flying RAM Payload Resources Requirements

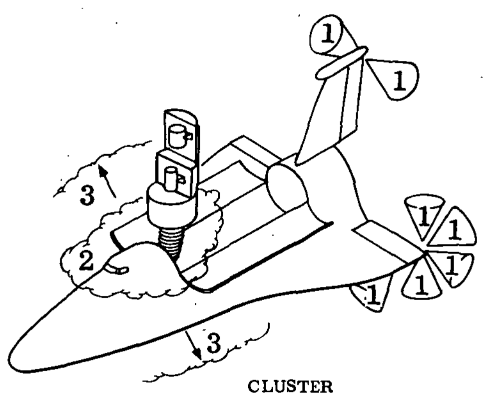


BASED ON 14 REPRESENTATIVE STATION-ATTACHED PAYLOADS
— — — IMPLEMENTATION PROVIDED

Figure 6-3. Station-Attached Payload Resource Requirements

In the reference free-flying astronomy payloads, heat is lost from large telescope apertures and added by the electrical power dissipated in the electronics racks. When total payload cooling and heating requirements for each free-flying RAM payload are summed, the net load is only a few hundred Watts. Computer-monitored thermal management is recommended to enable positive control and minimum temperature excursions. Thermal control shields, integral liquid jackets in telescope and instrument housings, and cold plates in electronics racks are used to maintain desired component temperatures by the thermal interface units.

6.1.3.2 Contamination. The space shuttle atmospheric environment is of critical importance to viewing payloads in the sortie mission (i.e., Astronomy, Earth Observations, Physics, and Communications/Navigation). A model of the environment for definition of countermeasures is shown in Figure 6-4. Typical ACPS jet locations are shown as sources of radially expanding cones of exhaust products. The angular composition and mass distribution is a complicated function of nozzle geometry and flow conditions, but most of the effluents will be found within 90-degree cones centered on each thruster axis.



SOURCE	MATERIAL	RATE
1 ACPS		
(A) HYDRAZINE	$NH_3 + N_2 + H_2$ + ANILINE	37 LB/HR (±0.5°)
OR	OR	OR
(B) HYPERGOLIC	$N_2 + H_2O + CO_2 + OH + O_2 + NO + H_2 + O + H$	56 LB/HR (±0.5°)
2 CABIN LEAKAGE	$O_2 + N_2 + H_2O$	1 LB/DAY
3 OUTGASSING	ORGANIC GASES	DESIGN DETERMINATION

Figure 6-4. Shuttle Contamination Model

In the reference shuttle configuration, twenty-six thrusters are located, 13 to a pod, on both wing tips and six thrusters are located atop the shuttle vertical stabilizer. Hydrazine monopropellant or hypergolic bipropellant fuel will be used. Cabin leakage emerges from structural seams, hatches, microscopic cracks, and window frames. Outgassing of nonmetallic materials (e.g., paints, plastics, and silicones) is a continuing process radiating in all directions. Potentially, particulate matter may dislodge and provide a contamination source from areas such as the shuttle cargo bay.

Analysis of sortie RAM configurations for contamination effects has resulted in limiting the necessity for shuttle ACPS firing by providing CMGs as an alternative means of stabilizing the shuttle during missions

requiring a contamination-free environment. Contamination monitors and potential countermeasures are:

Monitors

Optical
Mass Deposits
Mass Spectrometer

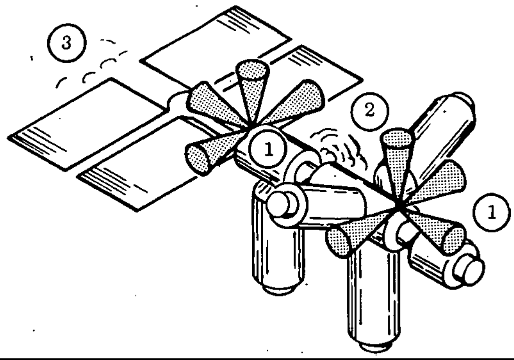
Countermeasures

Effluent Control
Differential Pressure
Shielding
Covers (removable)
Materials Selection
CMGs

Sortie RAM astronomy instruments can be enclosed in a shield that can be slightly pressurized during ascent and return to earth. The shield covers would be opened only after contamination levels have been reduced to acceptable levels. Each of the reference astronomy payloads includes contamination and environment sensors capable of monitoring the external contamination levels as well as the telescope, array, and thermal shield environments. Optical sensors are used for evaluating light-scattering contamination, mass deposition sensors for measuring contaminant deposition rates and quantity accumulated, and mass spectrometers for measuring types and quantities of contaminants.

Contaminants expelled by the space station propulsion system are represented by cones of expanding exhaust gas, as shown in Figure 6-5. There are four propulsion clusters on the crew operations module and the power/subsystems module. Each cluster contains low-thrust CO_2 jets and high-thrust monopropellant hydrazine jets. Most gas from the jets is contained in an angle of about 90 degrees. Cabin leakage emerges from structural seams, microscopic cracks, etc., directed in rather narrow streams. Organic molecules and particles outgassed from the solar panels and the painted vehicle surfaces are ejected in random directions.

An estimate of the free-flying RAM contamination sources and quantities are shown in Table 6-3. During ascent and entry, the payload enclosures containing contaminant susceptible optics and sensors are kept under positive pressure to prevent influx from the shuttle cargo bay. During transportation, open cathode and refrigerated sensors can be enclosed in evacuated containers. Contamination covers can be provided as payload integration equipment to instruments that do not have sufficient inherent shielding. Wherever optics or sensor protective covers are removed during servicing, a clean



SOURCES
① PROPULSION CLUSTER - TYPICAL INSTALL.
② CABIN LEAKAGE ZONE — SPHERICAL
③ OUTGASSING — SPHERICAL

ISS CONTAMINANTS			
SOURCE	MATERIAL	RATE OF DISCHARGE	RAM COUNTERMEASURE
① ACPS	HYDRAZINE CO_2	1.1 LB/DAY 4.8 LB/DAY	DIRECT AWAY FROM RAM, SHIELD INSTRUMENTS
② CABIN LEAKAGE	$N_2 + O_2 + H_2O$	10 LB/DAY	SHIELD/CLEAN OPTICS
③ OUTGASSING	ORGANIC CASES & PARTICLES	DESIGN DETERMINATION	PRE-CURE ORGANIC MATERIAL

Figure 6-5. Space Station Contamination Model

Table 6-3. Free-Flying RAM Contamination Model

Source	Quantity/Dump (lb/dump)
Propulsion	
H_2O	<0.01
H_2	0.08
NH_3	0.27
N_2	0.65
Hydrazine Aniline	0.004
Outgassing	Design Dependent

air shield will be used to blow particles away. Contamination monitors are provided to assess the effects of contaminant constituents outside the vehicle. This information is used to decide if the environment is sufficiently clean to open protective covers.

6.1.3.3 Film. Fogging of film from proton irradiation varies depending on the film type. The proton radiation dose that will result in a 0.2 net fogging density is indicated in Table 6-4 for several types of film, which are representative of those used for space photography. The 0.2 net density is a reference film fogging factor and not an experiment restriction.

Assuming that the cameras, film cassettes, or magazines will provide sufficient additional shielding to make the electron dose negligible, only the proton dose remains an important contributor. Table 6-5 shows the wide range of exposure time as a function

Table 6-4. Proton Dose to Produce 0.2 Net Density

Film Type	Proton Dose (Rad)	Energy (Me V)	Flux Proton (m^{-2} sec^{-1})
SC-5	1.6	>10	10^2 to 10^3
SO-101	12.0	>10	10^2 to 10^3
SO-392	12.0	>10	10^2 to 10^3
SWR	26.0	>10	10^2 to 10^3

Table 6-5. Days for Trapped Protons to Fog Film to a 0.2 Net Density

Orbit Altitude/ Inclination (n. mi/deg)	SC-5	SO-101 & SO-392	SWR
200/30	6.5 to 8.3	8 to 63	105 to 135
300/30	1.3 to 1.6	9.4 to 12	20 to 25
400/30	0.5 to 0.6	3.8 to 4.5	8.3 to 9.8
400/0	2.3 to 2.9	17 to 22	37 to 47
300/90	2.7 to 3.4	20 to 25	44 to 55
270/55	3.0 to 3.8	23 to 29	49 to 62
200/90	11.4 to 15	86 to 110	186 to 238

of orbit and film type for proton degradation. The range in days depicts minimum and maximum inherent structural protection. SC-5 film will receive a large increase in net density for most orbits unless additional shielding is provided. A film vault is required to store film for any payload carrying SC-5 film for even a seven-day flight.

6.2 EXPERIMENT INTERFACES

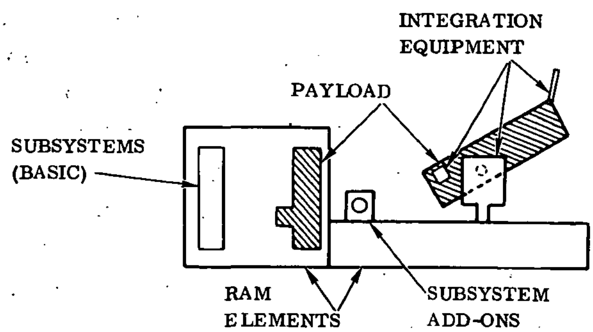
Gaps between experimental equipment and RAM payload carrier subsystem capabilities are filled with payload integration equipment. An analysis of capabilities has resulted in the integration equipment identified in this section. The RAM payload carrier interfaces with commercially available laboratory equipment are discussed.

6.2.1 PAYLOAD INTEGRATION EQUIPMENT. Payload integration equipment includes: 1) integration equipment necessary to install the experiment/payload in the carrier and 2) subsystem add-ons constituting modular additions to basic RAM payload carrier capabilities. Booms, gimbals, environment protective equipment (such as contamination covers, fine thermal controls, radiation shielding, or lint-free garments), subsatellite control, effluent control, and film storage are examples of integration equipment. These equipment items are not generally specified in experiment definitions but are needed to support unique payload characteristics or adapt the payload to the RAM payload carrier or mission. Add-ons include major integration hardware structure and functional equipment such as CMGs, peaking batteries, or other items related to special payload characteristics or frequency of use, which may be added in modular form to extend RAM payload carrier capability.

Table 6-6 identifies payload integration equipment in both categories and relates this equipment to experiment disciplines. The equipment installation varies with each discipline or representative payload, since it is dependent on payload definition and

Table 6-6. Payload Integration Equipment Summary

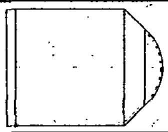
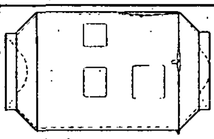
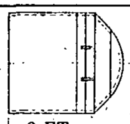
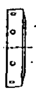
	Astronomy	Physics	Earth Observations	Communication/ Navigation	Materials Science	Technology	Life Sciences
INTEGRATION EQUIPMENT	Experiment installation structure Contamination monitor Fine thermal control Radiation protection Contamination protection Gimbals & controls Lint free garments	Experiment installation structure Contamination monitor Radiation protection Gimbals & control Film vault Boom Subsatellite adapter & controls Cryogenic system Lint free garments Effluent control	Experiment installation structure Contamination monitor Contamination protection Gimbals & control Film storage cabinet Booms Cryogenic system	Contamination monitor Contamination protection Gimbals & control Film storage cabinet Booms Subsatellite adapter & controls	Film storage cabinet Effluent control system + gas	Experiment installation structure Film storage cabinet Launch/ recovery adapter Teleoperator or Astronaut maneuvering unit	Experiment installation structure Film storage cabinet
SUBSYSTEM ADD-ON	CCTV Bulkhead Barrel section Pressurizable housing with hinged dome Pressure dome CMG Fixed-head star tracker Strapdown rate-gyro package Precise stability Data recorder Extra data tapes	Airlock Bulkhead Experiment structure (cosmic ray bay) Peak battery	Bulkhead Barrel section Pressure dome Peak battery Data recorder Extra data tape	Airlock Bulkhead Barrel section Pressure dome Peak battery & charger	CCTV Peak battery & charger Data recorder Extra data tape	CCTV Airlock Bulkhead Experiment structure (tank support) Data recorder Extra data tape	CCTV Data recorder Extra data tape 30 day add-on (expendables)



the characteristics of the payload itself (such as sensitivity to operations, pressurized versus unpressurized location, or natural and induced environment).

6.2.1.1 Structures and Airlocks. Payload-peculiar experiment operations and/or equipment mounting results in the requirement for structural integration hardware. Hardware items in this class are significant deviations to the basic structure and are peculiar to one or a select group of payloads. Typical major structural integration equipment based on the interface payloads is identified in Figure 6-6 and is described in the following paragraphs.

STRUCTURE

ITEM	CONFIGURATION	PAYLOAD DISCIPLINE APPLICATION
STATION DEPLOYABLE DOME 14 FT. DIA. x 17.5 FT. LONG		EARTH OBS. COMM/NAV.
STATION COSMIC RAY PHYSICS MODULE 14 FT. DIA. x 24 FT. LONG		PHYSICS
FREE-FLYING RAM PRESSURE COMP'T. EXTENSION 12 FT. DIA. x 6 FT. LONG		ASTRONOMY
FREE-FLYING RAM PRESSURE COMP'T EXTENSION & DOME 12 FT. DIA. x 14 FT. LONG		ASTRONOMY
SORTIE FLAT BULKHEAD -102 -IN. DIA.		EARTH OBS. COMM/NAV.

AIRLOCKS

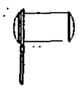
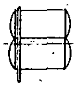
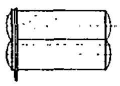
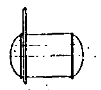
ITEM	CONFIGURATION	PAYLOAD DISCIPLINE APPLICATION
SORTIE/STATION AIRLOCK (1) 3.5 FT. DIA. x 6 FT. LONG		COMM/NAV.
SORTIE/STATION AIRLOCK (2) 3.5 FT. DIA. x 6 FT. LONG		COMM/NAV.
SORTIE/STATION AIRLOCK (3) 3.5 FT. DIA. x 11 FT. LONG		PHYSICS
SORTIE/STATION AIRLOCK 5.67 FT. DIA. x 6 FT. LONG		PHYSICS TECHNOLOGY

Figure 6-6. Major Structural Integration Hardware

A deployable, pressurizable dome on the station-attached RAM payload module permits servicing the Communication/Navigation and Earth Observations sensors when it is closed. The complete cosmic ray physics lab module is classed as integration structure and accommodates specialized payload detector bays, a large liquid helium dewar, a total absorption detector, and emulsion packages. It is installed on the end of a station-attached payload module and can be separately pressurized and operated at reduced pressure. The pressure compartment extensions for free-flying RAMs (Figure 6-6) provide a protective shell for telescopes, thermal shields for mirrors and instruments, and contamination covers. Flat pressure bulkheads are used on sortie RAM or RAM payload modules to mount payload-peculiar sensors, observation telescopes, antennas, and airlocks.

There are three basic RAM payload carrier airlock configurations. Man-rated airlocks for Technology and Life Sciences discipline payloads requiring EVA are provided by the shuttle and station. Scientific airlock configurations for the RAM payload carriers are shown in Figure 6-6. Up to three of the 3.5-foot-diameter airlocks are mounted in a single flat bulkhead. Cover plates are provided for the unused openings for configurations requiring less than three airlocks. The airlocks are configured in two lengths, with the driving requirement being the retracted length of booms used in space/plasma physics payloads. The larger diameter airlock is required for ingress-egress of the teleoperator and for physics and chemistry payloads. Communication/Navigation discipline payload airlocks accommodate overall layout requirements and provide manned access to certain instruments.

6.2.1.2 Booms and Gimbals. The reference Physics discipline payloads require three booms, which are deployed through the airlocks just described. The boom lengths are 10, 40, and 160 feet; each supports a two-degree of freedom gimbal at its tip.

The 160-foot boom length is required to sample the ambient region of space beyond the spaceship wake. The length is a compromise between the theoretically calculated wake (about 400 feet) and practical limitations imposed by weight and cost penalties. Subsatellites will be used in the more advanced payloads to probe beyond the limited reach of the 160-foot boom. The 40-foot boom is used for deployment of optical sensors, which are directed at selected targets. Generally, all three booms are simultaneously deployed either to meet the requirements of a single experiment or a group of synergistic experiments.

Gimbals are used to augment the pointing accuracy of the shuttle or station or to provide the capability for off-axis pointing for a variety of sensors. All sortie mission and station-attached reference Astronomy discipline payloads require one or more gimbals for telescope and array pointing. Many Earth Observation discipline sensors require the use of gimbals for pointing. Boom-mounted gimbals are required for space and plasma physics. The most critical gimbal requirement is in the Astronomy discipline. The selected sortie astronomy payload envelope and pointing requirements indicate a need for the six versions of gimbals shown in Table 6-7. These designs are capable of satisfying all reference astronomy mission payload requirements. Basically, there are two standard gimbals — a small five-axis and a large five-axis — with removable gimbal assemblies to enable attainment of gimbal configurations as needed.

For Earth Observation payloads, a common gimbal is supplied for the multispectral radiometer and the spectral polarimeter; other integration equipment gimbals are provided for individual sensors.

Table 6-7. Summary of Standard Gimbal Application for Astronomy

Small	Large
Two-Axis: Low background cosmic ray detector + aspect telescope Gamma ray spectrometer + aspect telescope Large x-ray counter array + aspect telescope	Two-Axis: Narrowband spectrometer/polarimeter array + aspect telescope
Four-Axis: IR Telescope (Blue Book) + aspect telescope	Four-Axis: IR telescope (Ames Research Center) + aspect telescope
Five-Axis: 0.3 M UV wide field + aspect telescope, 65 cm photopheliograph and Hα telescope	Five-Axis: X-ray spectroheliograph + solar UV spectrometer + Hα telescope

6.2.2 INTERFACE WITH COMMERCIALLY AVAILABLE LABORATORY EQUIPMENT. One of the NASA-supplied contractor guidelines for the RAM project is stated as follows:

> "8.2 Maximum use will be made of standard laboratory equipment where cost effective. Modification and space qualification testing will be minimized."

In conjunction with NASA/MSFC constract "Definition of Experiments and Instruments for a Communication/Navigation Research Laboratory" (NAS 8-27540), a RAM study team member, TRW systems, performed a survey of potential use of commercial hardware. Ten qualified vendors provided detailed information on the suitability of their hardware to meet anticipated RAM project environmental criteria and safety standards.

No supplier advocated direct use of commercial hardware without modification. Most modifications were concerned with factors such as safety, outgassing, flammability, load factors, vibration, temperature, RFI, and pressure. Material outgassing and flammability were not big problem areas due to the 14.7 psia O_2/N_2 operating environment. Most companies are now using suitable materials in their components, insulation, and packaging structure. The biggest problem seems to be the physical design

to meet safety standards in terms of elimination of cover glass over dials, rounding of corners, recessing of knobs and switches, and substitution of some thermal control device for fans.

It is recommended that the results of this and other applicable payload definition studies be transmitted to the potential instrument suppliers so that they may gradually incorporate improvements as their product line evolves. In this way, by the time the laboratory instrument complement is selected for the RAM project, most equipment could be used in an off-the-shelf configuration without the need for modification.

To facilitate the use of commercially-available laboratory equipment, RAM payload integration equipment includes a standard equipment mounting cabinet that provides the necessary physical and functional interfaces to accommodate such instruments. The cabinet contains an air-to-water heat exchanger and fans to circulate air within the cabinet, which is essentially a closed system. It also contains a power-converter/regulator and distribution unit which provides standard voltages of 12 Vdc, 28 Vdc, and 115 V 60 Hz as regulated power up to a total of 250 Watts. By using this type of equipment mounting cabinet, laboratory instruments that are usually convection cooled, could be employed in the pressurized RAM.

6.3 INTEGRATION HARDWARE

The approach to payload integration has had as an objective the design of laboratories and observatories that will economically provide the versatility required to be responsive to experiment requirements. The vehicle arrangement, structure, subsystems resources, and payload integration equipment are combined to provide the required flexibility to support a wide range of payloads and user requirements. The approach for the physical integration of payloads has been to provide each RAM payload carrier with a basic capability with respect to subsystems performance and accommodation volume. For specific payloads with greater or more stringent requirements, add-on subsystems are provided. For the short-duration sortie missions, these add-ons are designed to be easily and quickly installed or removed. For the long-duration free-flying or station-attached missions, the add-ons may be a more permanent type of installation.

Flexibility in the mounting of various internal payload equipment is provided by removable racks and panels that do not affect the basic structure of the RAM payload carrier (Figure 6-7). The consoles and/or equipment racks are mounted on channel supports bolted to threaded inserts in the floor. Inserts are installed in the floor for the different length channels required for various payloads. This arrangement permits rapid removal and replacement. A harness and utility trough is provided at the floor juncture with the side wall. Overhead equipment is mounted to removable honeycomb panels, as shown in Figure 6-7. Harnesses and/or tubing are routed through the adjacent utility trough to the equipment and then through disconnects to each panel.

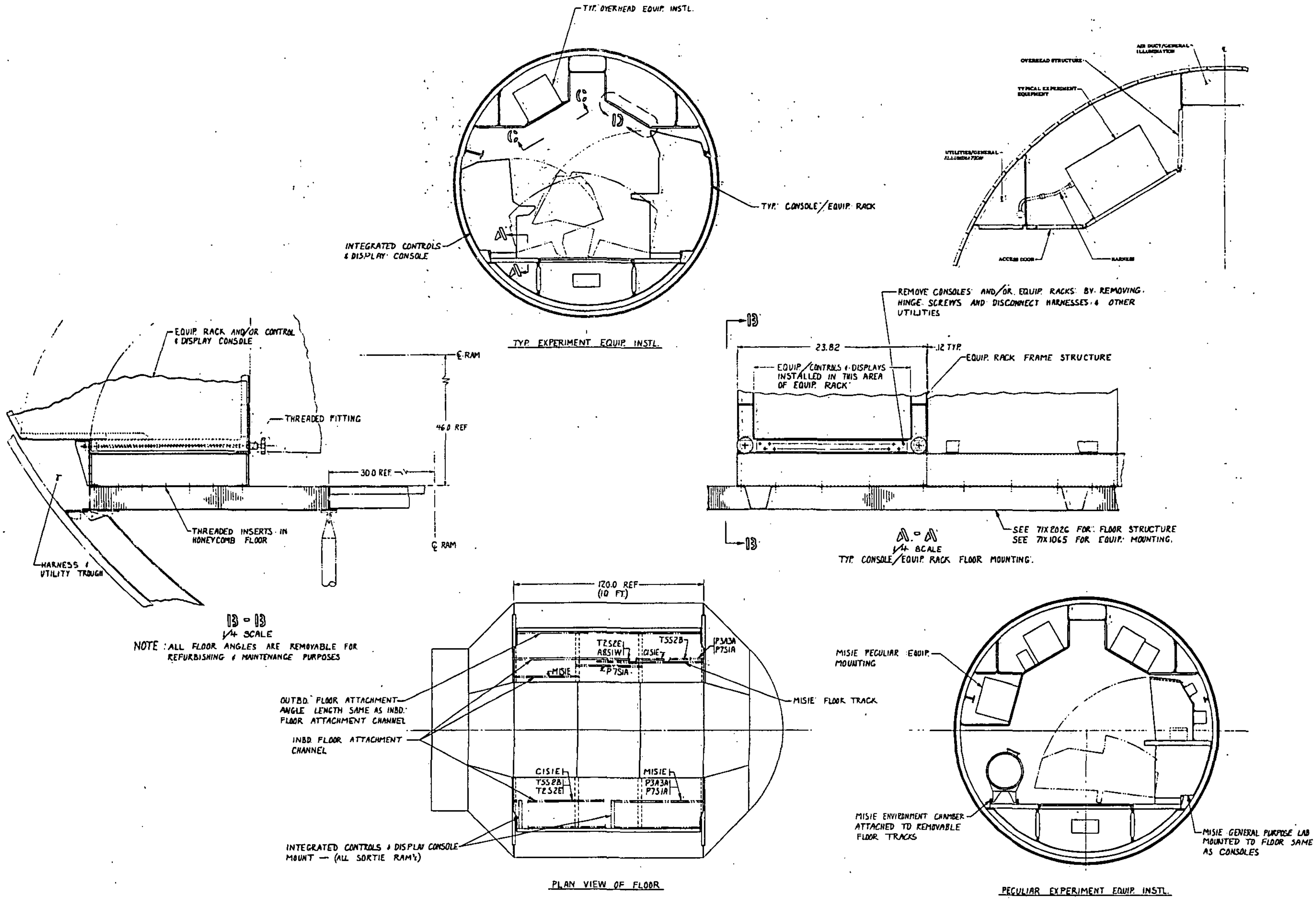


Figure 6-7. Payload Equipment Installation

External sensors and equipment are primarily attached to removable experiment-peculiar bulkhead structure and/or an external ring at the aft end of the sortie RAM or RAM payload module and/or the RAM pallet. The baseline pressurized RAM previously described has a standard spherical closure bulkhead that is attached by a bolt and seal attachment at the 102-inch-diameter aft ring of the conical bulkhead. For some payloads, this end closure is replaced by 102-inch-diameter experiment-peculiar pressure bulkheads, as illustrated in Figures 6-8 and 6-9.

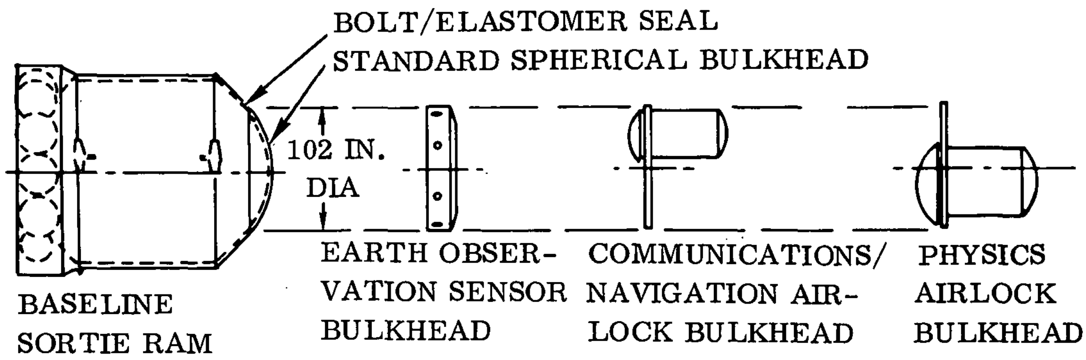


Figure 6-8. Experiment-Peculiar 102-Inch-Diameter Pressure Bulkheads

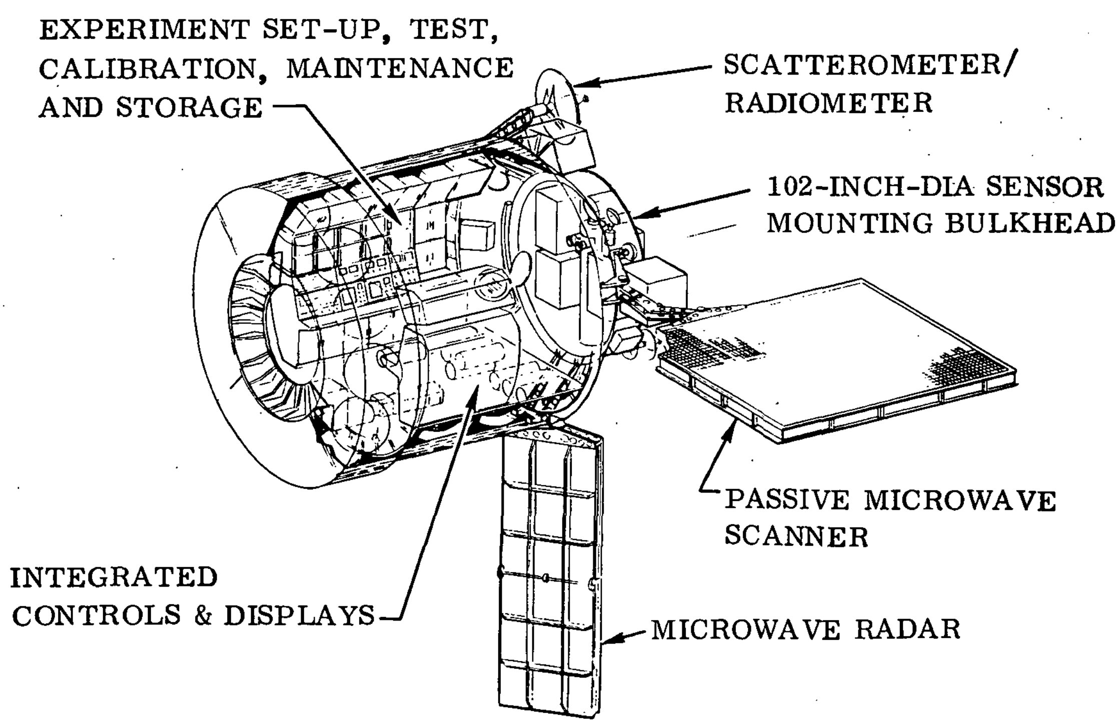


Figure 6-9. Integration of Earth Observations

Characteristics of all payload or experiment integration equipment identified in Table 6-8 are documented in the Experiment Requirements Library. The Experiment Requirements Library program (ERLIB) is a set of storage and retrieval routines used to produce summary lists of experiment and integration equipment for various combinations of experiments. Experiment names, equipment item inventory numbers, quantities, shared item codes, and location codes are filed in a random access file and indexed by experiment number and operating mode. Descriptive information on each equipment item including name, equipment class, dimensions, weight, volume, operating power, and other characteristics is filed in the random access file and indexed by item number. The random access file technique allows changes to individual items of stored data without having to recreate the entire data bank.

These payload integration equipment requirements were established in conjunction with knowledgeable experiment and subsystem specialists. Results of this equipment identification were supplied as input, and major items reflected in configuration and layout drawings. Each piece of payload integration equipment is also accounted for in the detailed mass properties report.

Major structural add-on items include the 102-inch-diameter experiment-peculiar pressure bulkheads for mounting sensors and airlocks. These replace a standard end closure by a bolted seal ring. Other major structure includes the added sidewall and pressure closures for free-flying and station-attached RAMs. Most of the Physics and one of the Technology discipline payloads require airlocks. Some of the Communications/Navigation payloads use an airlock as a design solution to meet sensor deployment/viewing angle requirements.

Experiment-integration equipment includes radiation and contamination protection, cryogenics, gimbal systems, and deployment booms. All sortie Astronomy payloads require one or two gimbals installed on the RAM pallet, along with the three CMG subsystem add-ons.

Tables 6-9 through 6-13 present weight summaries for the fully outfitted RAM elements with integrated reference payloads. The tables itemize the weights of the major equipment categories, i.e., basic RAM payload carrier, subsystem add-ons, and experiments. Total dry weight and launch weight are also given.

6.4 USER PROVISIONS

6.4.1 INTRODUCTION. The basic support capability of a payload carrier was determined from an analysis of the common demands of the representative payloads. Cost, development schedule, and integration schedule were also considered in establishing the standard or basic support capability of a RAM element or combination of elements. The net capability to support a given payload is equal to the total capability of the RAM elements, plus subsystem add-ons, plus optional payload integration equipment, minus payload carrier subsystem support requirements.

Table 6-8. Major Payload Integration Equipment

Reference Payload No.	①	Reference Payload Title	Experiment Integration Equipment: Expt. Instl. Structure	Contam. Monitor Set	Fine Thermal Control: Shroud	Fine Thermal Control: TIU*	Radiation Protect.	Contam. Protect.	Gimbals & Controls	Acceleration Isolators	Film Vault or Cabinet	Deployment Booms	Sub-Satellite Adapter & Controls	Cryogenic System	Lint-Free Garments ④	Effluent Contl Syst. + Gas	Launch/Recovery Adapter	Tele-Operator or AMU Syst.	RAM Payload Carrier Subsystem Add-Ons: CCTV	Airlock: 68 D x 72 L	Airlock: 42 D x 72 L	Airlock: 42 D x 132 L	Bulkhead (Dia)	Barrel Sect. (L)	Exper. Struct.	Dia Press. Dome	Peak Btry	Peak Btry + Btry Chgr + Wiring	CMG Syst.	Reaction Wheels	Data Recorder	Extra Tape Reels + Storage ③	30-Day Equipment + Expendables
A3S1B	A I	Austere Solar Astronomy (Telescope)		X	X	X	X	X	X										X										X				
A6S1B	A I	Austere IR Astronomy (Telescope)		X			X	⑤	⑤										X										X				
A8S1V	A I	Combined Austere Astronomy (Solar Telescope High Energy Array)		X	X (2)	X (2)	X	X	X (2)										X										X				
A8S1W	A I	Combined Austere Astronomy (UV Wide Field Telescope & High Energy Array)		X	X (2)	X (2)	X	X	X (2)										X										X				
A8S1X	A I	Combined Austere Astronomy (UV Narrow Telescope & High Energy Array)		X	X (2)	X (2)	X	X	X (2)										X										X				
A8S1U	A I	Combined Austere Astronomy (ARC Telescope & High Energy Array)		X	X	X	X	X ⑤	X (2) ㉖										X										X				
A8S1Z	A I	Combined Austere Astronomy (IR Telescope & High Energy Array)		X	X	X	X	X	X (2)										X										X				
A9S1J	- I	Combined Austere Astronomy (Solar Telescope & High Energy Array)		O	O (2)	O (2)	O	O	O (2)										O										O			O	
P5S1B	A -	Combined Space/Plasma Physics (Austere)		O					O (3)			O (3)			O							O (3)	O 102 in.				O						
P7S1A	A I	Combined Cosmic Ray/Physics & Chemistry (Austere)							X			X								X			X 102 in.										
P5S2A	A -	Combined Space/Plasma Physics (Intermediate)		O					O (3)			O (3)	O		O							O (3)	O 102 in.				O						
P8S2B	A -	Combined Space/Plasma/Cosmic Ray Physics (Intermediate)		O					O (3)			O (3)	O		O							O (3)	O 102 in.										
P7S3A	A -	Combined (Advanced) Cosmic Ray/Physics & Chemistry	X						O		O ②	O		⑤		⑤							O 102 in.				O						
E1S1N	A I	Earth Observation (Weather) - Austere		X				X	X (4)		X	X (3)		X ㉕									X 102 in.				X						
E1S1O	A I	Earth Observation (World Land Use Mapping) - Austere		X				X	X (3)		X	X (3)		X (2) ㉕									X 102 in.				X					X	
E1S1P	A I	Earth Observation (Air & Water Polution) - Austere		X				X	X (2)		X	X		X (2) ㉕									X 102 in.									X	
E1S1Q	A I	Earth Observation (Resource Location) - Austere		X				X	X (3)		X	X (2)		X (2) ㉕									X 102 in.				X					X	
E1S1R	A I	Earth Observation (Disaster Assessment) - Austere		X				X	X (2)		X	X (2)		X (2) ㉕									X 102 in.										
E1S1S	A I	Earth Observation (Ocean Resources) - Austere		X				X	X		X	X		X ㉕									X 102 in.									X	

NOTES:
① A = Later missions, I = Early missions
② Film vault.
③ 6 reels = nominal RAM payload carrier load.
④ Assumes RAM payload carrier provides 100,000 class air.
⑤ Included in current experiment definition.
* TIU = Thermal Interface Unit

㉕ Closed cycle systems
㉖ 1 is payload equipment & 1 is payload integration equipment
X = Applies to either early or later missions.
O = Applies only to indicated mission
( ) = Number in parenthesis indicates quantity

Reference Payload No.	①	Reference Payload Title	Experiment Integration Equipment: Expt. Instl. Structure	Contam. Monitor Set	Fine Thermal Control: Shroud	Fine Thermal Control: TIU*	Radiation Protect.	Contam. Protec.	Gimbals & Controls	Acceleration Isolators	Film Vault or Cabinet	Deployment Booms	Sub-Satellite Adapter & Controls	Cryogenic System	Lint-Free Garments ④	Effluent Contl Syst. + Gas	Launch/Recovery Adapter	Tele-Operator or AMU Syst.	RAM Payload Carrier Subsystem Add-Ons: CCTV	Airlock 68 D x 72 L	Airlock 42 D x 72 L	Airlock 42 D x 132 L	Bulkhead (Dia)	Barrel Sect. (L)	Exper. Struct.	Dia Press. Dome	Peak Btry	Peak Btry + Btry Chgr + Wiring	CMG Syst.	Reaction Wheels	Data Recorder	Extra Tape Reels + Storage ③	30-Day Equipment + Expendables
C1S1E	A I	Communication/Navigation (Lab I) - Austere		X				⑥	X ⑦			X ⑦	X (2)								X ⑬		X 102 in.										
C1S1F	A I	Communication/Navigation (Lab I) - Austere		X									X (2)										X 102 in.										
C1S2C	A -	Communication/Navigation (Lab II) - Intermediate		O				⑥	O (2) ⑦			O (2) ⑦	O (8)								O ⑬		O 102 in.										
M1S1E	A I	MS Configuration 1 - Operations Level 1														X			⑤									X			X	X	
M1S1F	A I	MS Configuration 1 - Operations Level 2														X			⑤									X			X	X	
M1S1G	A I	MS Configuration 1 - Operations Level 3														X			⑤									X			X	X	
M1S2B	A -	MS Configuration 2 - Operations Level 3														O			⑤									O				O	
T1S3A	A I	Complete Contamination Measurements													Piggyback Payload Carried on Other Missions																		
T2S1A	A I	Propellant Transfer Experiment	X																X														
T2S2E	A -	Combined Cryogenic Storage & Fluid Systems Experiment	O																														
T2(D)2B	A I	Detached Long-Term Cryogenic Storage Equipment	X																				X		X								
T3S1A	A -	Astronaut Maneuvering Unit Experiment									O						O	O ⑨	⑤	⑭													
T3S2B	A -	Maneuverable Work Platform Experiment									O						O	O ⑩	⑤	⑭													
T4S1A	A -	Short Duration Advanced Spacecraft Systems Test													Piggyback Payload Carried on Other Missions																		
T5S2B	A -	Teleoperator Experiment																	⑤	O			O 102 in.								O	O	
L8S1B	A -	Life Sciences Lab (Mini-7)								⑤									⑤	⑭											O	O	
L8S2B	A -	Life Sciences Lab (Mini-30)								⑤									⑤	⑭											O	O	O ⑪
L8(D)1A	A -	Bioresearch Module													Piggyback Payload Carried on Other Missions																		

NOTES:
① A = Later missions, I = Early missions
③ 6 Reels = Nominal RAM payload carrier load.
④ Assumes RAM payload carrier provides 100,000 class air.
⑤ Included in current experiment definition.
⑥ Sensitive equipment accessible for cleaning if required.
* TIU = Thermal Interface Unit
⑦ Booms with gimbal platform provided as current design solution.
⑨ Teleoperator for safety.
⑩ Teleoperator + Astronaut Maneuvering Unit for safety.
⑪ Includes shower plus increased N_2, food & storage, reactant & storage, waste mgmt, personnel gear, ECLS expendables.
⑬ Airlock(s) provided as current design solution (min. clear dia = 36 in.)
⑭ Airlock provided by shuttle, dimensions consistent with shuttle.
X = Applies to either early or later missions.
O = Applies only to indicated missions.
() = Number in parenthesis indicates quantity.

Table 6-8. Major Payload Integration Equipment (Continued)

Reference Payload No.	①	Reference Payload Title	Experiment Integration Equipment: Expt. Instl. Structure	Contam. Monitor Set	Fine Thermal Control: Shroud	Fine Thermal Control: TIU*	Radiation Protect.	Contam. Protect.	Gimbals & Controls	Acceleration Isolators	Film Vault or Cabinet	Deployment Booms	Sub-Satellite Adapter & Controls	Cryogenic System	Lint-Free Garments ④	Effluent Contl Syst. + Gas	Launch/Recovery Adapter	Tele-Operator or AMU Syst.	RAM Payload Carrier Subsystem Add-Ons: CCTV	Airlock 68 D x 72 L	Airlock 42 D x 72 L	Airlock 42 D x 132 L	Bulkhead (Dia)	Barrel Sect. (L)	Exper. Struct.	Dia Press. Dome	Peak Btry	Peak Btry + Btry Chgr + Wiring	CMG Syst.	Reaction Wheels	Data Recorder	Extra Tape Reels + Storage ③	30-Day Equipment + Expendables
A302D	A I	High Energy Stellar Astronomy Observatory		X	X (2)	X (3)	X	X ⑮							⑯								X 135 in. non-press	X 8 ft		X 135 in.							
A103B	A I	X-Ray Astronomy Observatory	X	X	X (4)	X(8)	X	X ⑮							⑯								X 135 in.										
A202B	A I	Large Space Telescope		X		X(2)	X ⑮	X ⑮							⑯								X ㉒							X (3)			
A303B	A I	Advanced Solar Astronomy Observatory	X	X		X(2)	X	X	⑤						⑯								X 135 in.	X 6 ft						X (3)	X		
T103B	A I	Complete Contamination Measurement													Piggyback Payload Carried on Other Missions																		
T401A	A I	Long Duration Advanced Spacecraft Systems Test													Piggyback Payload Carried on Other Missions																		
A703A	A I	Large Radio Astronomy Observatory		X			X	X															X										
A4A2A	A -	Narrow Field UV Astronomy		O			O	O	O																O ㉔								
A6A3A	A -	Austere Astronomy (IR Telescope)		O			O	O	O																O ㉔								
P6A3A-1	A -	Combined Space/Plasma Physics Lab.		O					O (3)		㉑	O (3)	O (4)		O							O ⑬	O 102 in.										
P6A3A-2	A -	Physics & Chemistry Lab.							O		O ㉑	O	O	⑤		O ⑮				O			O 102 in.										
P3A3A	A -	Cosmic Ray Laboratory					O				O												O 102 in.		O ⑰								
E1A3B	A -	Complete Earth Observations Lab		O				O	O (6)		㉑	O (6)		O (2) ㉕									O 102 in.	O 12 in.		O 168 in.							
E1A2B	A -	Intermediate Earth Observations Lab		O				O	O (3)		㉑	O (2)		O (2) ㉕									O 102 in.	O 12 in.		O 168 in.							
C1A2B	A -	Communication/Navigation (Lab II) - Intermediate		O					O (2) ⑳		㉑	O (2) ⑳	O (8)								O (2) ⑬		O 102 in.	O 12 in.		O 168 in.							
C1A3B	A -	Communication/Navigation (Lab III) - Complete		O					O (2) ⑳		㉑	O (2) ⑳	O (8)								O (2) ⑬		O 102 in.	O 12 in.		O 168 in.		O					
M1A3B	A -	MS Configuration 2 - Operations Level 4									㉑					O												O					
T1A3A	A -	Complete Contamination Measurement													Piggyback Payload Carried on Other Missions																		
T4A1A	A -	Medium Duration Advanced Spacecraft Systems Test													Piggyback Payload Carried on Other Missions																		
L8A1B-1	A -	Station Mission (Midi 30, F Module)								⑤	㉑																						
L8A1B-2	A -	Station Mission (Midi 30, BLH Module)									㉑									⑲													
L8A2B-1	A -	Station Mission (Maxi Nom, F Module)	O							⑤	㉑																						
L8A2B-2	A -	Station Mission (Maxi Nom, BLH Module)									㉑									⑲													

NOTES:
① A = Later missions, I = Early missions.
③ 6 reels = Nominal RAM payload carrier load.
⑤ Included in current experiment definition.
⑬ Airlock(s) provided as current design solution (minimum clear diam = 36 in.)
⑮ Provided by experiment or module design.
* TIU = Thermal Interface Unit
⑯ Provided in RSM for sortie mission.
⑰ Complete structural unit including thin windows.
⑲ Airlock provided by station.
⑳ Gimbal & boom provided as current design solution.
㉑ May use space station film vault.
㉒ Bulkhead included in experiment.
㉔ Complete pressurizable housing with hinged dome.
㉕ Closed cycle systems.
X = Applied to either early or later missions.
O = Applies only to indicated mission.
( ) = Number in parenthesis indicates quantity.

Table 6-9. Weight Summary for Fully Outfitted Sortie RAM with Reference Payloads

Payload Number	Basic Sortie RAM	Subsystem Add-Ons: Structure	Ind. Envir. Protect.	Docking	Prime Power Source	Elec. Conv. & Distr.	Data Management	Displays & Controls	Elect. Wiring	Total Add-Ons	Experiments	Dry Weight	Crew Equip.	Residuals Reserves In-Flight Losses	Launch Weight (lb)
A3S1B	10216	0	0	0	0	0	0	9	0	9	714	10939	341	1667	12947
A6S1B	10216	0	0	0	0	0	0	9	0	9	2710	12935	341	1861	15137
A8S1V	10216	0	0	0	0	0	0	9	0	9	1319	11544	341	1739	13624
A8S1W	10216	0	0	0	0	0	0	9	0	9	1273	11498	341	1744	13583
A8S1X	10216	0	0	0	0	0	0	9	0	9	1497	11722	341	1688	13751
A8S1U	10216	0	0	0	0	0	0	9	0	9	3194	13419	341	1874	15634
A8S1Z	10216	0	0	0	0	0	0	9	0	9	1658	11883	341	1725	13949
A9S1J	10216	0	0	0	0	0	343	9	0	352	1721	12289	341	1687	14317
P7S1A	10216	587	121	0	0	0	0	0	33	741	2721	13678	341	1825	15844
E1S1N	10216	393	78	0	292	18	0	0	5	786	4462	15464	341	1549	17354
E1S1O	10216	393	78	0	292	18	343	0	5	1129	4789	16134	341	1605	18080
E1S1P	10216	393	78	0	0	0	343	0	0	814	3598	14628	341	1552	16521
E1S1Q	10216	393	78	0	292	18	343	0	5	1129	4722	16067	341	1576	17984
E1S1R	10216	393	78	0	0	0	0	0	0	471	4217	14904	341	1529	16774
E1S1S	10216	393	78	0	0	0	343	0	0	814	2918	13948	341	1549	15838
C1S1E	10216	469	68	0	0	0	0	0	33	570	1708	12494	341	1624	14459
C1S1F	10216	393	78	0	0	0	0	0	0	471	1489	12176	341	1624	14141
M1S1E	10216	0	0	0	583	18	225	0	10	836	3100	14152	341	1747	16240
M1S1F	10216	0	0	0	583	18	225	0	10	836	3100	14152	341	1787	16280
M1S1G	10216	0	0	0	1457	18	432	0	25	1932	3361	15509	341	2002	17852
T2S1A	10216	0	0	0	0	0	0	9	0	9	0	10225	341	1689	12255
Servicer	10728	65	-43	70	0	13	0	9	20	134	2649	13511	441	2015	15967

Table 6-10. Weight Summary for Fully Outfitted RAM Pallet for Reference Payloads

Payload Number	Basic RAM Pallet	Subsystem Add-Ons: Guidance & Control	Subsystem Add-Ons: Displays & Controls	Subsystem Add-Ons: Total Add-Ons	Experiments	Dry Weight	In-Flight Losses	Launch Weight (lb)
A3S1B	2204	1418	33	1451	4206	7861	0	7861
A6S1B	2204	1418	33	1451	7238	10893	0	10893
A8S1V	2204	1418	33	1451	7038	10693	0	10693
A8S1W	2204	1418	33	1451	5597	9252	0	9252
A8S1X	2204	1418	33	1451	7335	10990	0	10990
A8S1U	2204	1418	33	1451	9217	12872	0	12872
A8S1Z	2204	1418	33	1451	7589	11244	0	11244
A9S1J(1)	2204	1418	33	1451	8144	11799	0	11799
T2S1A	2204	0	33	33	4359	6596	2700(3)	9296
T3S2B(2)	2204	0	33	33	2390	4627	0	4627

(1) Early capability only.

(2) Later capability only.

(3) Experiment fluid.

Table 6-14 summarizes the net capability of the baseline payload carriers to support the payload requirements listed. Also presented are the additional capabilities provided by optional integration equipment. The table is useful for selecting the optimum combination of RAM elements, subsystem add-ons, and integration equipment to accommodate a desired payload and to accomplished the mission objectives.

6.4.2 SORTIE RAM. The sortie RAM, together with a shuttle orbiter, can accommodate two payload/mission specialists in orbit under near zero-g conditions with opportunity for hemispherical viewing of space or the earth's surface. Up to 750 cubic feet of experimental equipment, with power demands up to 4.4 kW average, may be accommodated. The digital data subsystem provides recording capability at rates up to 67 Mbps. Up to 21 reels of magnetic tape can be provided, each with a storage capacity of 62 gigabits. The sortie RAM provides a general purpose subsystems/payload operations control and display console.

Table 6-11. Weight Summary for Fully Outfitted RSM for Reference Payloads

Payload Number	Basic RSM	Subsystem Add-Ons			Experiments	Dry Weight	Crew & Crew Equipment	Residuals Reserves In-Flight Losses	Launch Weight (lb)
		Displays & Controls	Interiors	Total Add-Ons					
A3S1B	10887	9	0	9	0	10896	733	2108	13737
A6S1B	10887	9	0	9	0	10896	733	2304	13933
A8S1V	10887	9	0	9	0	10896	733	2180	13809
A8S1W	10887	9	0	9	0	10896	733	2185	13814
A8S1X	10887	9	0	9	0	10896	733	2129	13758
A8S1U	10887	9	0	9	0	10896	733	2316	13945
A8S1Z	10887	9	0	9	0	10896	733	2167	13796
P5S1B	10887	0	0	0	0	10887	733	2333	13953
P7S1A	10887	0	0	0	0	10887	733	2308	13928
P5S2A	10887	0	114	114	0	11001	1016	2427	14444
P8S2B	10887	0	212	212	0	11099	1295	2618	15012
P7S3A	10887	0	0	0	0	10887	733	2311	13931
E1S1N	10887	0	0	0	0	10887	733	1990	13610
E1S1O	10887	0	0	0	0	10887	733	2046	13666
E1S1P	10887	0	0	0	0	10887	733	1992	13612
E1S1Q	10887	0	0	0	0	10887	733	2017	13637
E1S1R	10887	0	0	0	0	10887	733	1969	13589
E1S1S	10887	0	0	0	0	10887	733	1990	13610
C1S1E	10887	0	0	0	0	10887	733	2038	13658
C1S1F	10887	0	0	0	0	10887	733	2065	13685
C1S2C	10887	0	0	0	0	10887	733	2037	13657
M1S1E	10887	0	0	0	0	10887	733	1853	13473
M1S1F	10887	0	0	0	0	10887	733	1893	13513
M1S1G	10887	0	0	0	0	10887	733	1825	13445
M1S2B	10887	0	0	0	0	10887	733	2563	14183
T2S1A	10887	9	0	9	0	10896	733	2131	13760
T2S2E	10887	0	0	0	0	10887	733	2142	13762
T3S1A	10887	0	212	212	0	11099	1295	2150	14544
T3S2B	10887	9	0	9	0	10896	733	2157	13786
T5S2B	10887	0	0	0	0	10887	733	2180	13800
L8S1B	10887	0	212	212	0	11099	1295	2588	14982

Table 6-12. Weight Summary for Fully Outfitted RAM Payload Module for Reference Payloads

Payload No.	Basic Element: Sortie 18 ft	Basic Element: Sortie 32 ft	Basic Element: Station Attached 18 ft	Basic Element: Station Attached 32 ft	Subsystem Add-Ons: Structure	Induced Environ. Protect.	Docking	Prime Power Source	Electr Conver & Distrib	Data Management	Electr Wiring	Thermal Control	Interiors	Total Add-Ons	Experiment	Dry Weight	Crew & Crew Equip.	Residuals Reserves In-Flight Losses	Launch Weight (lb)
A3S1B	5798				0	0	0	0	0	0	0	0	0	0	714	6512	447	176	7135
A6S1B	5798				0	0	0	0	0	0	0	0	0	0	2710	8508	447	215	9170
A8S1V	5798				0	0	0	0	0	0	0	0	0	0	1319	7117	447	215	7779
A8S1W	5798				0	0	0	0	0	0	0	0	0	0	1273	7071	447	176	7694
A8S1X	5798				0	0	0	0	0	0	0	0	0	0	1497	7295	447	176	7918
A8S1U	5798				0	0	0	0	0	0	0	0	0	0	3194	8992	447	215	9654
A8S1Z	5798				0	0	0	0	0	0	0	0	0	0	1658	7456	447	176	8079
P5S1B		8744			1126	443	0	292	18	0	170	0	0	2049	4373	15166	447	448	16061
P7S1A	5798				587	139	0	0	0	0	33	0	0	759	2841	9398	447	240	10085
P5S2A		8744			1126	443	0	292	18	0	170	0	28	2077	5185	16006	550	480	17036
P8S2B		8744			1126	443	0	0	0	0	165	0	55	1789	8003	18536	653	480	19669
P7S3A	5798				587	139	0	0	0	0	33	0	0	759	13448	20005*	447	363	20815
E1S1N	5798				393	78	0	292	18	0	5	0	0	786	4462	11046	447	215	11708
E1S1O	5798				393	78	0	292	18	139	5	0	0	925	4789	11512	447	215	12174
E1S1P	5798				393	78	0	0	0	0	0	0	0	471	3598	9867	447	215	10529
E1S1Q	5798				393	78	0	292	18	0	5	0	0	786	4722	11356	447	215	12018
E1S1R	5798				393	78	0	0	0	0	0	0	0	471	4217	10486	447	215	11148
E1S1S	5798				393	78	0	0	0	139	0	0	0	610	2918	9326	447	215	9988
C1S1E	5798				469	68	0	0	0	0	33	0	0	570	1708	8076	447	239	8762
C1S1F	5798				393	78	0	0	0	0	0	0	0	471	1489	7758	447	215	8420
C1S2C	5798				733	157	0	0	0	0	60	0	0	950	3875	10623	447	239	11309
M1S1E	5798				0	0	0	583	18	186	10	0	0	797	3100	9695	447	551	10693
M1S1F	5798				0	0	0	583	18	186	10	0	0	797	3100	9695	447	551	10693
M1S1G	5798				0	0	0	1457	18	287	25	0	0	1787	3361	10946	447	789	12182
M1S2B		8744			0	0	0	1457	18	287	25	0	0	1787	5317	15848	447	428	16723
T2S1A	5798				0	0	0	0	0	0	0	0	0	0	0	5798	447	215	6460
T2S2E	5798				0	0	0	0	0	0	0	0	0	0	7300	13098	447	215	13760
T3S1A	5798				0	0	0	0	0	0	0	0	55	55	2426	8279	653	176	9108
T3S2B	5798				0	0	0	0	0	0	0	0	0	0	2840	8638	447	176	9261
T5S2B	5798				587	139	0	0	0	151	33	0	0	910	1952	8660	447	238	9345
L8S1B		8744			0	0	0	0	0	186	0	0	55	241	5056	14041	653	396	15090
P6A3A-1				10444	1126	443	0	0	17	0	165	0	0	1751	9961	22156*	124	800	23080
P6A3A-2				10444	587	139	0	0	17	0	33	0	0	776	5972	17192	124	800	18116
P3A3A			7367		5	-48	237	0	0	0	0	0	0	194	1540	9101	124	820	10045
E1A2B				10444	393	78	0	0	0	0	0	0	0	471	5760	16675	124	916	17715
E1A3B				10444	393	78	0	0	0	0	0	0	0	471	7853	18768	124	916	19808
C1A2B			7367		733	157	0	0	17	0	66	0	0	973	4492	12832	124	768	13724
C1A3B			7367		733	157	0	0	17	0	66	0	0	973	4932	13272	124	800	14196
M1A3B				10444	0	0	0	1649	18	0	180	330	0	2177	5356	17977	124	800	18901
L8A1B-1				10444	0	0	0	0	0	0	0	0	0	0	11621	22065*	124	800	22989
L8A1B-2				10444	0	0	0	0	0	0	0	0	0	0	4773	15217	124	768	16109
L8A2B-1				10444	0	0	0	0	0	0	0	0	0	0	14232	24676*	124	800	25600
L8A2B-2				10444	0	0	0	0	0	0	0	0	0	0	5171	15615	124	768	16507

*Exceeds 20,000 lb dry weight limit.

The supporting shuttle enables up to one Mbps of communication to earth for experiment operations coordination. Guidance, navigation, and attitude stabilization is provided by the shuttle, using its attitude control subsystems. Under nominal orbit and load conditions, air coolant is available for payload equipment from the sortie RAM cabin in a selectable range of 65°F to 85°F and coldplates are provided with a temperature range of 75°F to 95°F.

Table 6-13. Weight Summary of Fully Outfitted Free-Flying RAM for Reference Payloads

Payload Number	Basic Element		Subsystem Add-Ons										Experiment	Dry Weight	Residuals Reserves In-Flight Losses	Launch Weight (lb)
	Shuttle Supported	Space Station Supported	Structure	Induced Environ. Protection	Docking	Prime Power Source	Electr. Conver. & Distrib.	Guidance & Control	Manage-ment	Communi-cations	Electr. Wiring	Total Add-Ons				
Shuttle Supported (Initial and Full Capability)																
A1O3B	9774		1200	118	70	41	22	0	0	174	145	1770	13904	25448*	690	26138
A3O3B	9774		1813	471	70	339	53	95	102	174	152	3269	9934	22977*	690	23667
A5O2D	9774		2003	647	70	0	22	0	0	174	70	2986	3205	15965	690	16655
Station Supported (Full Capability Only)																
A1O3B		9933	1200	118	70	36	154	0	0	102	145	1825	13904	25662*	1180	26842
A3O3B		9933	1813	471	70	330	185	95	102	102	152	3320	9934	23187*	1180	24367
A5O2D		9933	2003	647	70	0	154	0	0	102	70	3046	3205	16184	1180	17364

* Exceeds 20,000 pound dry weight limit.

Table 6-14. RAM Payload Support Capabilities

Parameter	Sortie RAM	Sortie RAM + RAM Pallet	RAM Payload Module + RSM	RAM Payload Module + RAM Pallet + RSM	Station-Attached RAM Payload Module	Free-Flying RAM
Basic Payload Capabilities						
1. Payload Equipment Volume (ft^3)	750	Sortie RAM - 750 Pallet - 2500	18-ft RAM Payload Module - 900 32-ft RAM Payload Module - 2000	RAM Payload Module - 900 Pallet - 2500	18-ft RAM Payload Module -900 32-ft RAM Payload Module -2000	920
2. Payload Crew Size/ Manhour per Day	2/21.5	2/21.5	4 to 6/45.5 to 69.5	4 to 6/45.5 to 69.5	4 to 6/40 to 60	2/21.5 (in-orbit servicing)
3. Electrical Power Total, unregulated (±15%) 28 vdc ±5%/115v, 400 Hz	 4.4 kW, 600 kW-hr 1500W/1250va	Same as sortie RAM	Same as sortie RAM except energy up to 1000 kW-hr	Same as RAM payload module + RSM	 3.2 kW 1500W/1250 va	 1.3 kW 500W/500 va
4. Data Acquisition Data Rate Storage (bits per reel/No. of reels)	 67 Mbps $6.2 \times 10^{10}/21$	 67 Mbps $6.2 \times 10^{10}/21$	 67 Mbps $6.2 \times 10^{10}/35$	 67 Mbps $6.2 \times 10^{10}/35$	 25 Mbps 1.0×10^{10}/stored in station	 1.24 Gbps $5.1 \times 10^{10}/1$
5. Control and Display	Payload dedicated C&D console, mission event timers, intercom, caution and warning	Console: same as sortie RAM plus closed circuit TV on manipulator arms to view pallet.	Console in RSM same as for sortie RAM	Same as sortie RAM + pallet.	C&D provided by station RAM has intercom, caution and warning, payload-dedicated C&D	(Console in sortie RAM for in-orbit servicing)
6. Communications (Transmission Capacity)	Shuttle-provided. S-band: 1 Mbps peak Max contact - 3 to 11% of time	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Station provided TDRS: 10 Mbps S-band: 1 Mbps peak Max contact - 3 to 11% of time	TDRS: 10 Mbps digital 10 MHz analog
7. Guidance, Navigation, and Control Pointing acc Stability Position (n. mi) Velocity (fps)	Shuttle provided ±0.5 deg ±0.03 deg/Sec ±1.0 ±10	Shuttle provided ±0.5 deg ±0.03 deg/Sec ±1.0 ±10	Shuttle provided ±0.5 deg ±0.03 deg/Sec ±1.0 ±10	Shuttle provided ±0.5 deg ±0.03 deg/Sec ±1.0 ±10	Station provided ±0.25 deg ±0.05 deg/Sec ±1.0 TBD	 ±1 Arc Sec. ±0.5 Arc Sec. 0.3 (Via 2.0 TDRS)
8. Thermal Control* Air temp (°F)/heat rejection (Btu/hr) Cold plate temp/ heat rejection (Btu/hr)	 80 to 100/0 to 3100 75 to 95/0 to 3100	 Same as sortie RAM Same as sortie RAM	18 ft / 32 ft 80 to 120/0 to 3700 / 70 to 115/0 to 7500 90 to 105/0 to 3700 / 85 to 95/0 to 7500	 80 to 120/0 to 3700 90 to 105/0 to 3700	18 ft / 32 ft 70 to 80/0 to 2900 / 85 to 105/0 to 6600 65 to 70/0 to 2900 / 85 to 100/0 to 6600	 60 to 115/0 to 5000*
9. Viewports	Three viewports, 12-inch diameter, located at aft 45 deg conical section provide hemispherical coverage.	One viewport, 12-inch diameter, located at aft 45 deg conical section.	Same as sortie RAM+ pallet.	Same as sortie RAM + pallet.	Same as sortie RAM	None

*Air and cold plate temperature ranges shown are for 3σ worst case orbital conditions and include effects of degraded thermal control surfaces.

Table 6-14. RAM Payload Support Capabilities, Contd

Parameter	Sortie RAM	Sortie RAM + RAM Pallet	RAM Payload Module +RSM	RAM Payload Module + RAM Pallet + RSM	Station-Attached RAM Payload Module	Free-Flying RAM
Basic Capabilities (Contd)						
10. Feedthroughs	Two 8-inch-diameter feed-through ports located at aft 45 deg conical section	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	Provided in experiment integration bulkhead per individual payload requirements.
Integration Equipment and Add-on Options						
1. Airlocks No./diam (ft)/ length (ft)	3/3.5/11 or 1/5.7/6	None	3/3.5/11 or 1/5.7/6	None	3/3.5/11 or 1/5.7/6	None
2. Special Bulkheads	102-inch outer diameter for three 42-inch outer diameter airlocks; 102-inch outer diameter for one 72-inch outer diameter airlock; 102-inch outer diameter sensor mounting	None	Same as sortie RAM	None	Same as sortie RAM	136-inch outer diameter for installation of instruments and/or for pressurizable access
3. Deployment Booms	Three standard booms of lengths 10, 40, and 160 ft	None	Same as for sortie RAM	None	Same as for sortie RAM	None
4. Gimbals	Three 2-axis gimbals installed on deployment booms	Two standard gimbals: 1. Large, 5-axis 2. Small, 5-axis	Same as for sortie RAM	Same as for sortie RAM + pallet.	Same as for sortie RAM	None
5. Fine Thermal Control	None	Two standard shrouds: 1. 76-inch outer diameter x 140 inches long 2. 87-inch outer diameter x 140 inches long + radiator add-ons + thermal interface unit.	None	Same as for sortie RAM + pallet.	Standard thermal control shrouds and thermal interface units + radiator add-ons	Special thermal control shrouds and standard thermal interface units per individual payload requirements + radiator add-ons
6. Guidance, Navigation and Control Pointing Accuracy (arc-sec) Stability (arc-sec)		±1.0 (Add CMGs 10.5 and gimbals)		±1.0 (Add CMGs 10.5 and gimbals)		±1.0 ±0.005 (Add reaction wheels)
7. Peaking Battery	14 kW-hr increments, up to 4 increments	Same as sortie RAM	Same as sortie RAM	Same as sortie RAM	90 kW, 22 kW-hr	None

Special options such as airlocks, bulkheads, deployment booms, gimbals, and peaking batteries may be added to the basic sortie RAM to meet unique requirements.

6.4.3 <u>SORTIE RAM PLUS RAM PALLET</u>. For experiments requiring external gimbals, structures, or large arrays of equipment, a RAM pallet may be added to the sortie RAM, enabling stowage or installation of up to 2500 cubic feet of experiment and payload integration equipment. To enable fine pointing, stabilization, and control for experiment groupings such as in astronomy, up to two sets of gimbals may be installed on the RAM pallet. The RAM pallet, together with the shuttle orbiter, may be stabilized to ±0.5 arc-second by CMG add-ons without incurring contamination or interference from the shuttle orbiter ACPS engines.

Control Moment Gyros (CMGs) of the type and size designed for Skylab are used to control the attitude of the shuttle/RAM payload carrier assembly, principally to eliminate potential shuttle RCS contamination and improve base stability (Figure 6-10). To avoid a significant increase in the required number of CMGs, shuttle orientation is constrained to nose-along-the-orbit-normal. This shuttle orientation constraint and the typical payload composition of two independently pointed experiments require that the attitude of the telescope be independent of the RAM pallet. The gimbaling assembly provides three-axis wide-angle gimbaling for hemispherical telescope coverage and attitude isolation relative to the base of the RAM pallet. It also provides two axes of narrow-range experiment line-of-sight fine pointing, based on error signals provided by the experiment. Fixed-head star trackers and a strapdown rate gyro package are mounted on the gimbaling assembly to provide all-attitude sensing.

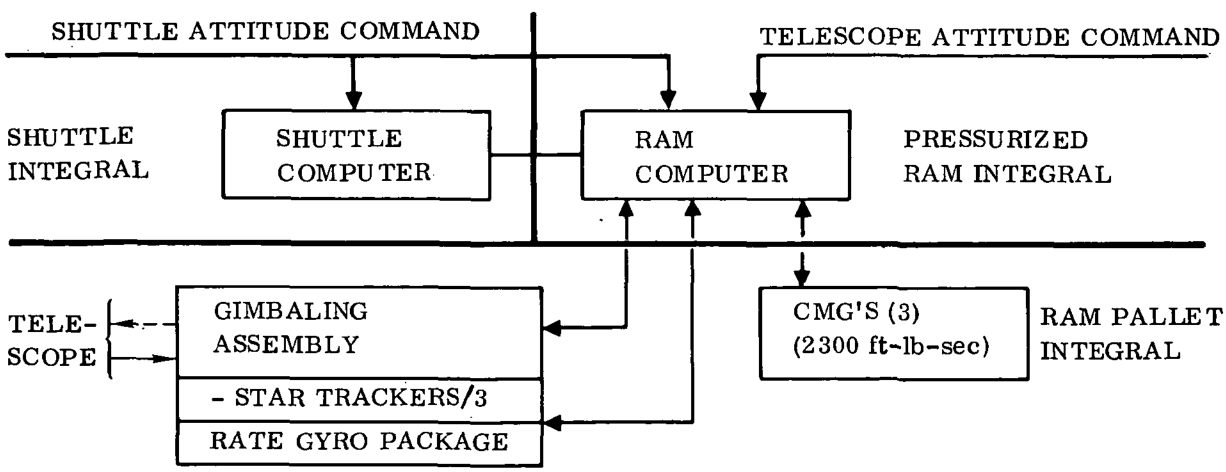


Figure 6-10. RAM Pallet Astronomy GN&C Integration Equipment Configuration

Two identically configured gimbaling assembly sizes are provided. The smaller unit accommodates about 60 percent of the Astronomy discipline experiments (Figure 6-11). Beyond the azimuth/elevation gimbals, the concept is the same as that of the Skylab Apollo telescope mount. Skylab CMGs were selected because of their availability. Fixed-head star trackers and a rate gyro package, which have been selected for the free-flying RAM, were also selected for the RAM pallet.

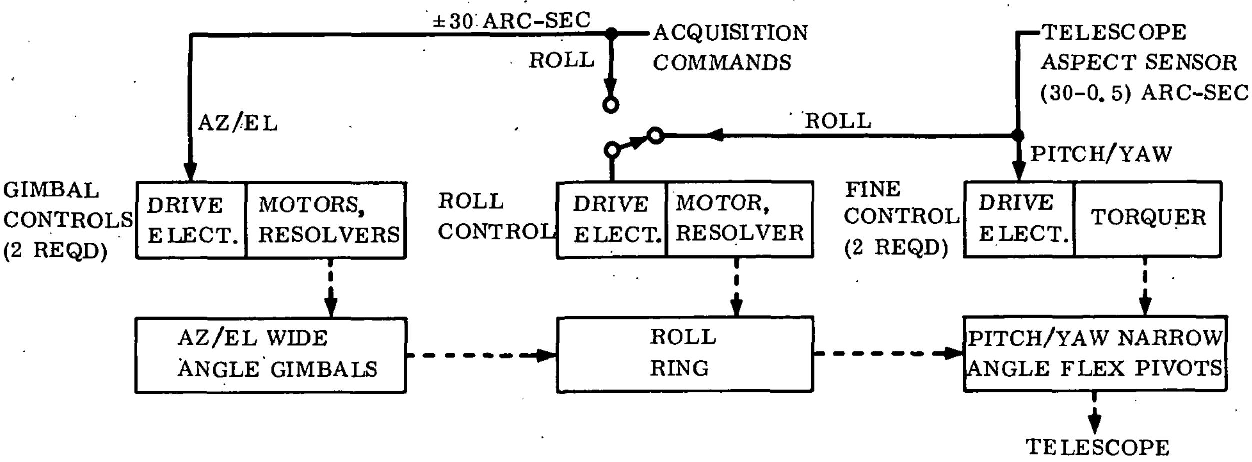


Figure 6-11. Gimbaling Assembly Configuration

Basic thermal control for the pallet-mounted equipment is provided by the sortie RAM. Any part of the cold-plate cooling load of the sortie RAM, up to 3100 Btu/hr, can be provided to the RAM pallet with thermal control within the same temperature limits (75°F to 95°F) as the sortie RAM. When heat loads exceed 3100 Btu/hr, or an experiment needs to be controlled to lower temperatures within a tighter tolerance, an additional radiator section may be installed on the back of the RAM pallet. For more stringent temperature control, such as is required for the 65 cm photoheliograph telescope (50° ± 1.8°F) the addition of a thermal shroud is required.

The sortie RAM integrated C&D console may be used to control and display information obtained by payload equipment on the RAM pallet. Space is provided in the integrated console to mount experiment-peculiar electronics needed in addition to standard control/display services.

6.4.4 RAM PAYLOAD MODULE PLUS RSM (OR SORTIE RAM). A greater sortie experiment support capability can be accomplished by combining a RAM support module (or sortie RAM) and a RAM payload module. There is an 18-foot-long RAM payload module and a 32-foot-long RAM payload module. Nine hundred cubic feet of space is available for payloads in the 18-foot module and 2000 cubic feet in the 32-foot module. The RSM enables maintaining a payload crew up to six crewmen, including the two in the shuttle, in space for up to seven days. Electric power, up to 4.4 kW, is

available to a maximum of 1900 kW/hr. Peaks of up to 90 kW may be accommodated with peaking batteries. Capability exists for recording data at rates up to 67 Mbps and storing up to 62 gigabits/reel. Up to 35 reels can be provided. Communication is via the shuttle and ground network system for 3 to 11 percent of each orbit at rates up to 1 Mbps. Guidance and navigation is accurate to ± 1 n. mi. and 10 fps. Basic attitude pointing accuracy provided by the shuttle is ± 0.5 deg, and angular stability is 0.03 deg per sec.

Under nominal orbital and load conditions, air coolant is available for payload equipment from the RAM payload module and RSM in a selectable range from 65°F to 85°F, and cold plates are provided with a temperature range of 75°F to 95°F. Under 3σ worst-case orbital and load conditions, somewhat wider temperature excursions are expected.

Three viewports are available at the outer end of the RAM payload module to enable visual monitoring of external experiments.

For external experiments, additional optional equipment such as airlocks, special bulkheads, deployment booms, and gimbals are available. An integrated control and display console located in the RSM is available for experiment operations.

6.4.5 RAM PAYLOAD MODULE PLUS RAM PALLET PLUS RSM (OR SORTIE RAM). A RAM payload module, a RAM pallet, and a RSM (or sortie RAM) provide a greater combined capability for experiments requiring large gimbals or experiment structures. The RSM makes it possible to augment the two payload crewmen in the orbiter by four additional payload crewmen to enable around-the-clock operation of experiments. Because of shuttle cargo bay length constraints, only the 18-foot RAM payload module can be accommodated in conjunction with a RSM (or sortie RAM) and RAM pallet.

The 18-foot RAM payload module provides 900 cubic feet of experiment available volume and the RAM pallet about 2500 cubic feet exposed to space. A maximum of 4.4 kW and 1900 kW/hr are available. Peaks of up to 90 kW can be handled by a peaking battery.

Basic thermal control for the RAM pallet-mounted equipment is provided by the RSM or sortie RAM. Any part or all of the cold-plate cooling load of the RSM (or sortie RAM) up to 3700 Btu/hr can be provided to the RAM pallet, with thermal control within the same temperature limits (90° F to 105° F) as the RSM (or sortie RAM). Gimbals, CMGs, and fine thermal control options are also applicable to augment the RAM element capabilities.

6.4.6 STATION-ATTACHED RAM PAYLOAD MODULE. Two sizes of station-attached RAM payload modules are available — an 18-foot-long version with 900 cubic feet of space for experiments and a 32-foot-long version with 2000 cubic feet of space. The space station will support four to six payload crew members for around-the-clock operation of some of the experiment groupings (payloads).

Approximately 3.2 kW of electrical power is available from the space station. From this total, 1500 Watts is expected to be regulated 28 Vdc, and 1250 VA is 115V, 400 Hz. The balance would be unregulated 115 Vdc.

The space station can also record experiment data at rates up to 25 Mbps, storing the data on tape of 10 gigabits per reel.

Payload control and display functions are provided by the space station. The RAM payload module includes caution and warning signals as well as payload (experiment) decicated test, control, and display units.

The space station provides a means for transmission of data, either real-time or post-real-time via TDRS to ground centers for experiment support at rates up to 10 Mbps.

Station attitude accuracy is ±0.25 degree and stability is ±0.05 deg/sec.

Under nominal orbital and load conditions, air coolant is available for payload equipment from the RAM payload module in a selectable range from 65° F to 85° F, and cold plates are provided with a temperature range of 70° F to 90° F. Under 3σ worst-case orbital and load conditions, somewhat wider temperature excursions are expected. Other optional equipment such as airlocks, special bulkheads, gimbals, and deployment booms can be installed to augment the RAM payload module to respond to experiment grouping requirements.

6.4.7 FREE-FLYING RAM. The basic free-flying RAM is 22 feet long and contains 920 cubic feet of space available to payload (experiment) equipment in addition to space allocated to subsystems (508 cubic feet) and to payload crew access ways (580 cubic feet). Additional internal space is available by adding a cylindrical section to the RAM payload carrier. Nominal length of the free-flying RAM with payload equipment installed is limited to 58 feet; for shuttle orbital altitudes greater than 240 n. mi., however, the overall length of the free-flying RAM is limited to 53 feet. This reduction in length is necessary for installation of orbital maneuver subsystem kit in the orbiter cargo bay to provide the propellant for increased velocity necessary to attain higher orbital altitudes.

The baseline net available power for experiments is 1.3 kW, of which up to 500 Watts is regulated at ±5 percent and up to 500 VA is 115V, 400 Hz. Solar array panels can be added for higher average power up to 2.2 kW.

The free-flying RAM data acquisition capability is 51 gigabits of data storage on one reel recorded at rates up to 1.24 Gbps. Data can be transmitted to earth stations at rates up to 10 Mbps digital or 10 MHz analog via TDRS. Normal control and display functions are accomplished from remote consoles located in a servicing sortie RAM

or from an earth-based center. Only special test, local control, and display indicators as needed for quick test and servicing of the configuration are provided in the dedicated experiment equipment.

Basic guidance and navigation locates the vehicle position to ±1 n.mi. Basic pointing and stability are ±1 arc-sec and ±0.5 arc-sec, respectively. Vehicle position data to 0.03 n.mi. and velocity to 2 fps based on tracking data received via the TDRS will be available. Add-on reaction wheels or image motion compensation will improve stability to ±0.005 arc-sec.

The basic free-flying RAM module is capable of maintaining cold-plate temperature between 80°F and 115°F at worst-case orbits and heat loads up to 5000 Btu/hr. If a lower experiment temperature and closer control is desired, additional fine thermal control equipment and increased radiator area can be used. With fine thermal control equipment, plus additional radiator area, any temperature between 30°F (272°K) and 75°F (297°K) can be selected and held to ±1.8°F (1.°K).

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 7

RELIABILITY, MAINTAINABILITY, AND SAFETY

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SECTION 7

RELIABILITY, MAINTAINABILITY, AND SAFETY

Reliability and maintainability characteristics of the RAM payload carrier subsystems were reviewed to 1) determine failure modes by a failure mode and effects analysis, 2) identify, eliminate, or minimize critical failure modes, 3) implement RAM payload carrier designs that tend to enhance the probability of mission success and module recovery, and 4) determine the optimum cost effectiveness of added redundancy to reduce maintenance costs.

The results of this review indicate that all RAM payload carrier subsystems incorporate the minimum redundancy that is essential to prevent loss of life and/or complete loss of a module. Redundancy is sometimes achieved by duplicating like components and sometimes by using the capability inherent in another subsystem.

Scheduled and unscheduled maintenance analyses were performed for each RAM payload carrier subsystem to determine the payload crew hours for the maintenance tasks performed as part of ground operations and flight operations. The analyses also indicated the times for replacement and checkout, and the spares requirements, which assisted in minimizing the on-orbit time required for the maintenance of free-flying RAMs.

Refurbishment requirements were analyzed to define areas where there would be a potential reduction in program cost by exceeding the minimum redundancy requirements and decreasing the servicing requirements. Since refurbishment costs depend on modifications and availability of time to refurbish, a logic diagram was prepared to identify modification costs due to added or new equipment items, wearout costs due to returning used items to new condition, replacement of items made obsolete by improvements, and costs due to random failure. These costs were then compared to costs of new equipment.

System safety analyses showed that a definitive set of safety criteria is required for the experiments to ensure the safety of RAM payload carrier. The following paragraphs describe the reliability, maintainability, and safety analyses.

7.1 RELIABILITY/MAINTAINABILITY ANALYSIS

7.1.1 FAILURE MODE AND EFFECTS ANALYSIS (FMEA). The purpose of the FMEA is to evaluate the baseline designs of the RAM element subsystems to determine the effects of failure mode on safety and performance. An important output of the FMEA is identification of those components and failure modes that can result in loss of life or module (Criticality 1). The FMEA also identifies those components and

failure modes that can result in loss of ability to conduct the experiment or to meet all the experiment objectives (Criticality 2). All other failure modes are calssified as Criticality 3.

The following single-point failures were identified as Criticality 1:

a. Sortie RAM or RSM electrical power subsystem: O_2 tank and H_2 tank rupture.

b. Free-flying RAM propulsion subsystem: N_2 tank and N_2H_4 tank rupture or leakage.

Table 7-1 shows the hazard associated with each of these items. In each case, the rationale for retention is to provide adequate safety margins and pressure relief in the RAM element design.

The FMEA also identified the following redundant hardware whose next failure results in loss of life or loss of module.

a. Free-flying RAM propulsion subsystem: N_2 pressurant tank and thruster module (6).

b. Free-flying RAM communications and data management subsystem: Ku-band antenna, Ku-band RF switch, and S-band RF switch.

c. All RAM payload carrier thermal control subsystems: Space radiators, interloop heat exchanger, freon accumulator, sublimator, waste accumulator, thermal storage element, and fuel cell heat exchanger.

Table 7-1. Criticality 1 Items List

Item Identification and Function	Failure Mode	Failure Effect/Hazard	Corrective Action
Sortie RAM or RSM Electrical Power			
O_2 Tank – Provides storage for reactant for fuel cell operation.	Rupture (Explosion)	Loss of experiment power and possible external structure damage. Tanks are located outside of habitable volume.	Design will provide adequate margins and pressure relief.
H_2 Tank – Provides storage for reactant supply for fuel cell operation.	Rupture (Explosion)	Loss of experiment power and possible external structural damage. Tanks are located outside of habitable volume.	Design will provide adequate margins and pressure relief.
Free-Flying RAM Propulsion			
Pressurant Tank – Storage N_2 gas at high pressure.	Rupture or Leakage	Possible loss of vehicle due to structural damage or loss of attitude stabilization necessary for retrieval.	Design will provide adequate margins and pressure relief.
Propellant Tank – Stores hydrazine propellant	Rupture or Leakage	Possible loss of vehicle due to structural damage or loss of attitude stabilization necessary for retrieval.	Design will provide adequate margins and pressure relief.

7.1.2 RELIABILITY DESIGN CRITERIA. The determination of required redundancy to preclude critical failures was guided by the following items, which summarize the more significant reliability design criteria. (The complete reliability/maintainability design criteria are presented in Volume III of the RAM Technical Data Document, Appendix A.)

a. All critical (failure results in loss of life or loss of module) subsystems/functions will be designed for sustaining any credible combination of failures.

b. Active or standby redundancy automatically activated upon failure of the prime equipment is required for critical functions affecting crew survival.

c. In addition to built-in redundancy, alternative modes of operation are acceptable to fulfill redundancy requirements when their use does not create the need for additional hardware.

d. Critical (failure will result in either loss of life or loss of module) failure modes will be provided redundant means of failure detection plus either a third means of detection or a means of failure verification. Failure verification may be accomplished by determining that the detection equipment is functioning properly.

e. Systems or circuits whose malfunction could result in unsafe or potentially hazardous situations will be monitored. The monitoring equipment will provide adequate data to allow corrective action.

f. All RAM/RSM subsystems that incorporate an automated fail-operational capability will be designed to provide crew notification and data management subsystem cognizance of component malfunction until the anomaly has been corrected.

g. Conservative factors of safety will be provided where critical single failure points cannot be eliminated (pressure vessels, plumbing, etc.).

h. As a goal, free-flying RAMs will be designed to ensure their retrieval and recovery by the shuttle.

The following is a brief summary of the major redundancy design features of the RAM element subsystems.

a. <u>Free-Flying RAM Propulsion Subsystem</u>. The design provides redundant independent gas pressurant bottles for shuttle-supported free-flying RAMs. These bottles will have a high margin of safety to safeguard against rupture and loss of pressurant supply. Two redundant propellant tanks provide 100 percent quantity margin for each reaction control subsystem module. All thrusters are redundant to preclude loss of thrust, and CMG units can provide limited backup capability for free-flying RAM attitude control.

b. <u>Pressurized RAM Environmental Control and Life Support (EC/LS) Subsystem.</u> All critical components are redundant and excess O_2 and N_2 is provided for contingencies or emergencies. If the cabin atmosphere gas supply or the CO_2 control function is lost, the residual volume of O_2 in the cabin is adequate and CO_2 content is acceptable for six men for about seven hours – enough time for abort and recovery in a prime area. Pressure suits, face masks, and connections for each are provided for six men. Power supply buses from the electrical power subsystem are redundant for essential EC/LS loads.

c. Electrical Power Subsystem (EPS). The sortie RAM and RSM provide two redundant essential power buses (A and B), added redundancy in monitor/control units, and the capability to connect and use shuttle power for essential loads (essential buses to offset two failures) during the abort phase. The free-flying RAM provides for additional solar array capacity to compensate for deterioration in service. Free-flying RAM recovery can be accomplished with only three of the eight arrays. Solar array power is automatically transferred to the redundant essential buses if the primary bus or array power fails.

d. Free-Flying RAM Communications and Data Management Subsystem (CDMS). The design includes redundancies to preclude loss of tracking and command. Power supply buses from the EPS are redundant for critical functions and alternate systems provide backup for critical CDMS components.

e. Sortie RAM and RSM Onboard Checkout System (OCS). Redundancies for all critical OCS components are provided. A redundant power supply bus for essential loads to preclude loss of caution and warning is provided by the EPS.

f. Sortie RAM and RSM Controls and Displays. The design uses redundant power supply buses from the EPS for essential loads and provides redundancy in the panel displays for hazardous indications. For payload crew action items, use of computer as backup for automatic correction and use of a printer as a source of failure data as a backup for loss of caution and warning indication is planned.

g. Free-Flying RAM Guidance, Navigation, and Control. The subsystem precludes loss of guidance and stabilization by the use of redundant components and redundant buses for essential loads from the EPS.

h. Thermal Control. For all RAM payload carriers, the subsystem design precludes loss of thermal control by the use of redundant coolant pumps and coolant loops.

The critical functions and components for each RAM element and subsystems discussed above and the corrective action for loss of critical components are presented in Table 7-2.

7.1.3 RELIABILITY/MAINTAINABILITY OPTIMIZATION ANALYSIS. The purpose of this analysis was to optimize subsystems redundancy against total costs, including hardware and operations. The FMEA was used to determine the baseline (minimum) redundancy requirements and to identify active and standby backups necessary to meet mission performance requirements, ensure safe operation, identify critical failure, and provide for control and recovery of the RAM element under failure conditions. Added redundancy was then used to improve reliability and reduce the projected number of failures per year. The cost of the added redundancy was then compared with the baseline subsystem and repair costs to obtain an optimum redundancy versus cost configuration.

Table 7-2. Critical Functions and Components for Each Element and Subsystems

Subsystem	Element	Loss of Critical Function	Loss of Critical Components	Corrective Action
Electrical Power	Sortie RAM, RSM	Loss of electrical power	a. Loss of fuel cell b. Loss of main feeder lines c. Loss of monitor/control unit d. Loss of main bus	a. Shuttle provides power for essential loads. b. Shuttle power and feeder lines are available for use. c. Redundancy is provided in monitor/control unit. d. Redundant essential bus A or B will be used.
	Sortie Payload Module	Loss of electrical power	Loss of main bus	Redundant essential bus A or B will be used
	Free-Flying RAM	*Loss of electrical power*	a. *Loss of array sections* b. Loss of main bus	a. *Array sections are over-designed about 32% to compensate for* deterioration in service; only 3 of 8 arrays required for recovery. b. Switch power and loads to remaining bus.
Thermal Control	Sortie RAM, RSM, Station Attached Payload Module, Free-Flying RAM	Loss of thermal control	a. Loss of coolant pump b. Loss of coolant c. Failed temperature control valve	a. Coolant pumps are redundant. b. Coolant loops are redundant. c. Redundant coolant loop and valve are available for use.
	Sortie Payload Module	Loss of thermal control	Loss of coolant	Coolant loops are redundant
Environmental Control and Life Support (EC/LS)	Sortie RAM, RSM	Loss of module pressure	a. System component failures b. Loss of electrical power c. Loss of O_2/N_2 d. Pressure vessel rupture	a. Critical components are redundant; pressure suits and face mask connections may be used in emergency. b. Power supply buses are redundant for essential loads. c. Excess gas is supplied for emergency use; O_2 bottles are redundant for recovery; one cabin volume of gas is adequate for recovery with 6 men. d. Pressure suits available for all crew members; evacuate to orbiter or attached modules in emergency.
		Loss of CO_2 control	a. Component failures b. Unit saturation	a. Critical components are redundant; pressure suits and face masks are available in emergency. b. Spare canisters available; pressure suits and face masks; cabin CO_2 content may be maintained within safe limits for about 7 hours for 6 men; evacuate to the orbiter.
	Sortie Payload Module	Loss of module pressure	System component failures	Critical components are redundant; pressure suits and face mask connections may be used in emergency.
Environmental Control and Life Support (EC/LS), Atmosphere Control and Pressure Control	Free-Flying RAM	Loss of module pressure	System component failures	Critical components are redundant; pressure suits and face mask connections may be used in emergency.
Onboard Checkout Subsystem (OCS)	Sortie RAM, RSM, Sortie Payload Module, Pallet, Free-Flying RAM	Loss of caution and warning indication	a. Loss of power b. Critical components failures	a. Power supply buses are redundant for essential loads. b. Critical components are redundant.
Controls and Displays	Sortie RAM, RSM, Free-Flying RAM	Loss of caution and warning indication	a. Loss of power b. C&D panel failures	a. Power supply buses are redundant for essential loads. b. Indicators for hazardous situations are redundant; for crew action items, the computer may be used as backup for automatic correction; printer also may be used as a source of failure data.
	Sortie Payload Module	Loss of caution and warning indication	Loss of power	Power supply buses are redundant for essential loads.
Communication and Data Management	Sortie RAM, RSM, Sortie Payload Module Pallet, Free-Flying RAM	Loss of tracking and command	a. Loss of power b. Critical component failures	a. Power supply buses are redundant for critical functions. b. Redundant units and/or alternative systems for backup are provided.
Guidance, Navigation, and Control (GN&C)	Pallet, Free-Flying RAM	Loss of guidance and stabilization	a. Component failures b. Loss of electrical power	a. Critical components are redundant. b. Main power buses are redundant for essential loads.
Propulsion	Free-Flying RAM	Loss of thrust	a. Loss of gas pressurant b. Loss of propellant c. Loss of thrusters	a. Independent modules provide redundancy for shuttle-supported RAMs. High margin of safety for gas bottles is provided. b. Two redundant tanks for each module provide 100% quantity margin. c. Thrusters are redundant – CMG units can provide limited backup capability for module attitude control.

Figure 7-1 shows the methodology and approach of the optimization analysis using the sortie-mission RSM/RAM payload module combination as an example. Three graphs are presented; the first is a representation of the sortie RAM subsystem cost increase resulting from increasing the subsystem reliability by adding redundancy to achieve a decrease in the number of failures per year. The second graph shows the calculated cost of aborting missions and returning the sortie RAM to earth for repair during a ten-year operational period (REP baseline) as a function of the number of projected failures per year. The third graph is a summation of the first two curves and represents the total cost, with the minimum point of the total cost determining the optimum subsystem reliability (or the least-total-cost point and related projected failures per year).

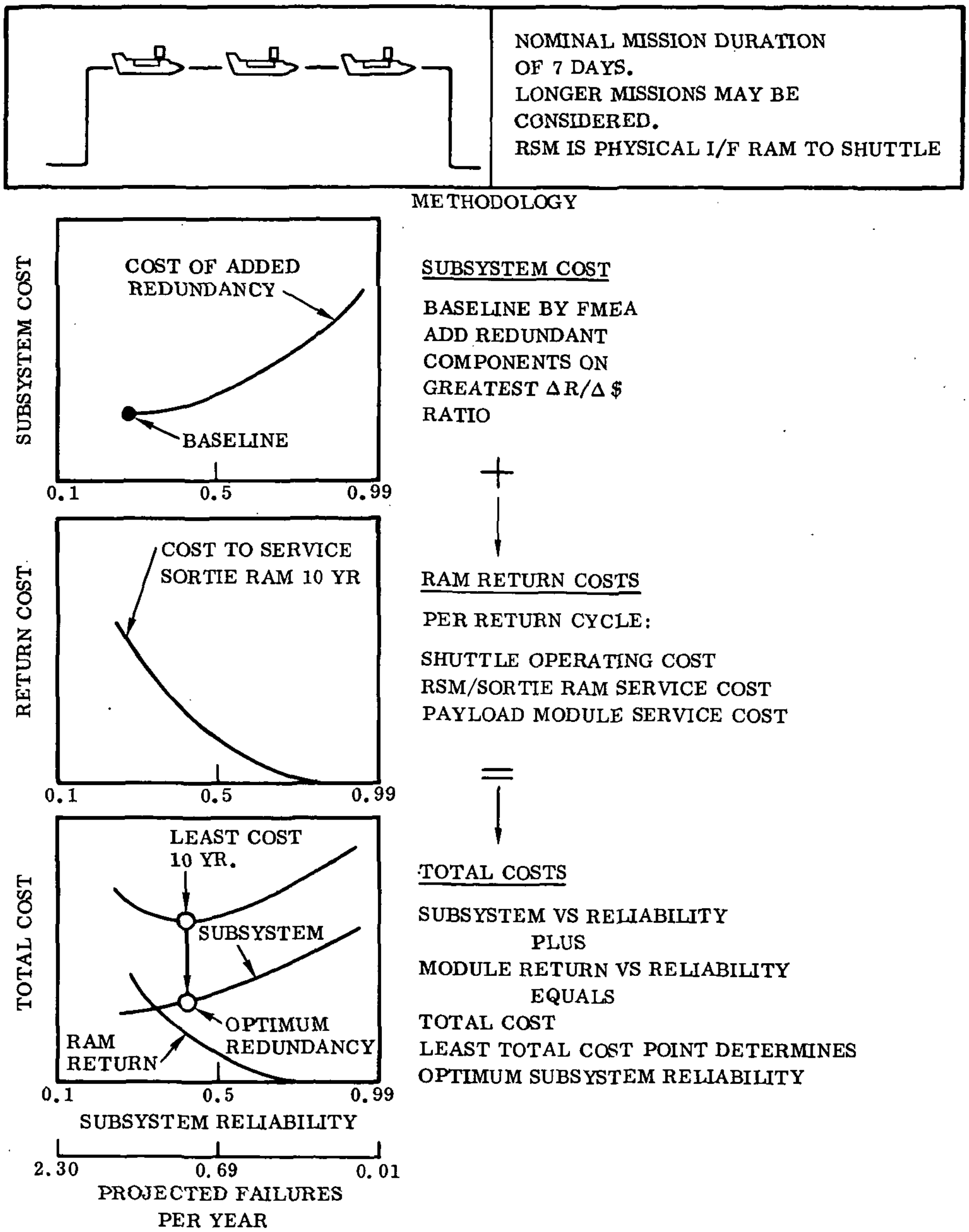

Figure 7-1. Methodology of All Sortie RAM Subsystems for Redundancy

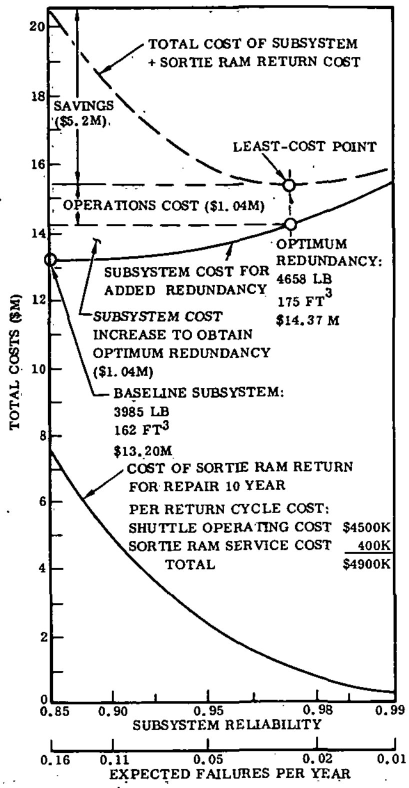

Figure 7-2. Optimization of all Projected Sortie RAM Subsystems for Redundancy

Figures 7-2, 7-3, and 7-4 show the results of the optimization analysis for the sortie RAM, space station-supported free-flying RAM and shuttle-supported free-flying RAM, respectively. Table 7-3 shows the results of an analysis to define the expected weight, volume, and cost differences associated with 1) functional design, 2) design that meets Criticality 1 constraints, and 3) design associated with optimum (reliability redundancy) for the sortie RAM, shuttle-supported free-flying RAM, and station-supported free-flying RAM. Based on the projected net savings in the program cost, the cost of increased redundancy is justified.

7.1.4 SCHEDULED AND UNSCHEDULED MAINTENANCE ANALYSIS. Scheduled and unscheduled maintenance analyses were performed for each subsystem of the free-flying RAM. The primary function of the maintenance analysis was to determine the payload crew hours required for the maintenance tasks. This information, including the frequency of

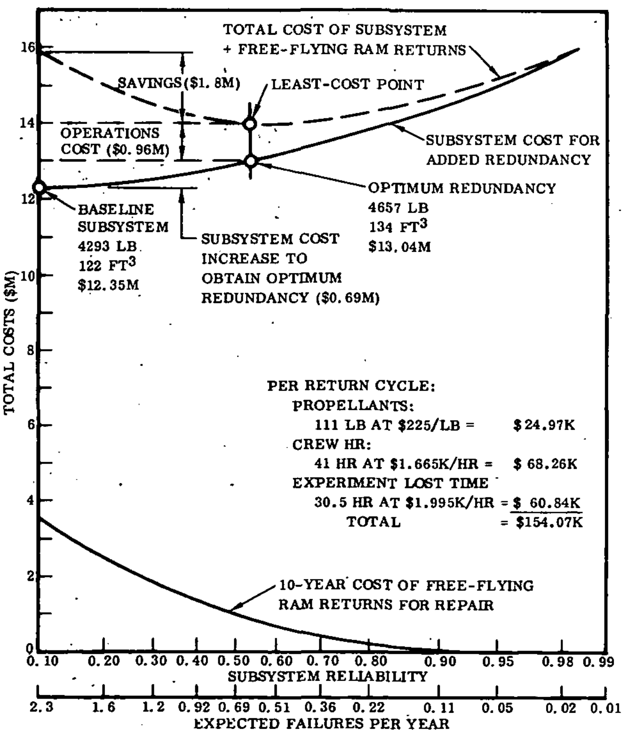

Figure 7-3. Optimization of all Projected Station-Supported Free-Flying RAM Subsystems for Redundancy

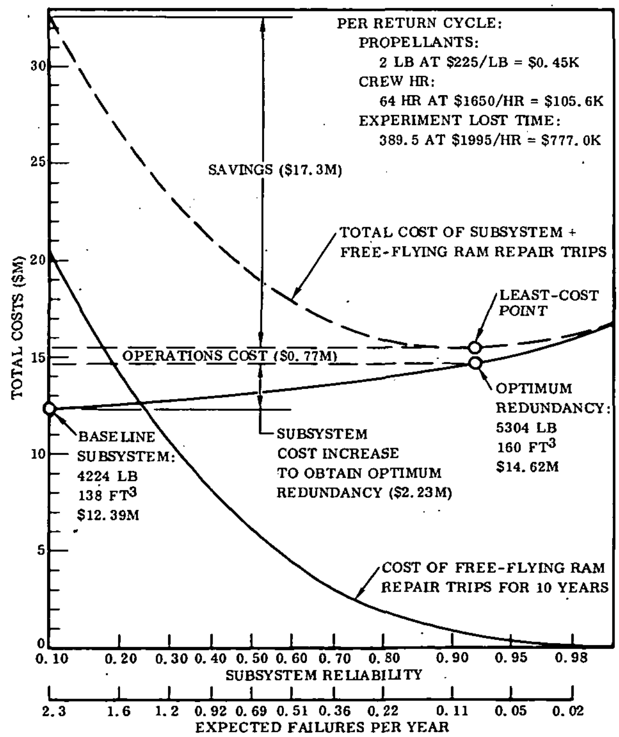

Figure 7-4. Optimization of all Projected Shuttle-Supported Free-Flying RAM Subsystems for Redundancy

Table 7-3. Summary of Weights, Volumes, and Costs for RAM Missions

Mission Mode	Functional Design	To Meet Criticality 1 Constraints	Optimum Redundancy for Minimum Total Program Cost	Increased Cost Over Baseline Design	Net Savings in Total 10-year Program Cost
Sortie RAM					
Weight (lb)	3931	3985	4658		
Volume (ft^3)	161	162	175		
Cost ($M)	12.55	13.20	14.37	1.17	5.20
Shuttle-Supported Free-Flying RAM					
Weight (lb)	3876	4224	5304		
Volume (ft^3)	117	138	160		
Cost ($M)	11.28	12.39	14.62	2.23	17.30
Station-Supported Free-Flying RAM					
Weight (lb)	3947	4293	4657		
Volume (ft^3)	117	122	134		
Cost ($M)	11.37	12.35	13.04	0.69	1.82

scheduled maintenance, is necessary for the development of a detailed timeline analysis of a free-flying RAM servicing mission. The unscheduled maintenance concept for on-orbit repairs is to make replacement at the component and/or assembly levels. By using the free-flying RAM onboard checkout system, the existing failures and spares requirements can be determined prior to launch of a service mission, thereby minimizing the on-orbit time required by the crew.

For scheduled maintenance, times to accomplish the indicated action at the specified interval were developed. Since a free-flying RAM is unpressurized while the experiment is being conducted, it must be pressurized after docking to the shuttle/sortie RAM or space station to permit maintenance. The time required for this was included in the maintenance analysis. If maintenance operations require use of pressure suits, either IVA (inside RAM element) or EVA (outside RAM element), the time required for this was recorded in the maintenance analysis. However, pressurized shirtsleeve maintenance operations are stressed and pressure-suit operations considered only when mandatory. Besides providing maintenance times (the primary function), the maintenance analysis included necessary data on task complexity, special tools, and other special requirements.

Since sortie missions are relatively short (seven days), no unscheduled maintenance is contemplated (i.e., the subsystems design will provide sufficient redundancy through an optimization analysis to provide a high degree of confidence for mission success). This approach precludes expensive lost time in space and the requirement for specifying and carrying spares aboard.

Table 7-4 summarized on-orbit scheduled and unscheduled maintenance times required for the free-flying RAM. The figures are average for a six-month period and based on a reliability of 0.92. The figures are based on optimized free-flying RAM subsystems. A complete file of scheduled and unscheduled maintenance analysis sheets is contained in the RAM Technical Data Document, Appendix A of Volume III, Technical Data Document.

Table 7-4. Free-Flying RAM Maintenance Summary

Unscheduled Maintenance

Subsystem	Average Payload Crew Hours for Repair (hr/yr)		Average Spares	
	EVA	Shirtsleeve	Weight (lb/yr)	Volume (ft^3/yr)
Controls and Displays	0	0.05	0.05	0
Propulsion	0	0	0.12	0.06
Electrical Power	0	2.09	11.09	2.09
Communications and Data Management	0	3.74	9.85	0.23
Guidance, Navigation and Control	0	10.41	161.19	3.33
Thermal Control	0	0.37	0.25	0.02
		16.68	182.55	5.73
		(8.34 hr/6 mo)	(91.27 lb/6 mo)	(2.86 ft^3/6 mo)

Scheduled Maintenance

Subsystem	Average Payload Crew Hours for Repair (hr/yr)	Average Spares	
		Weight (lb/6 mo)	Volume (ft^3/6 mo)
Guidance, Navigation and Control	2.94	243.5	5.97
Structure	2.0	7.0	0.10
Electrical	4.8	580.0	5.53
Data Management	2.17	1.3	0.25
	11.91	831.8	11.85

7.1.5 RAM REFURBISHMENT/REUSE STUDY. A refurbishment study was conducted on the major reference payloads. Using the REP (Figure 1-1) as a timeline, the study was concerned with those actions necessary to prepare the RAM payload carrier and payload for the next mission identified by the REP.

The analysis logic used in this study is shown in Figure 7-5. Figure 7-6 shows study results of the RAM payload carrier/payload-discipline configurations analyzed. The bars in Figure 7-6 indicate the new (replacement) cost, the comparable refurbish cost and the savings for each. These are unit production costs only, and do not include R&D costs.

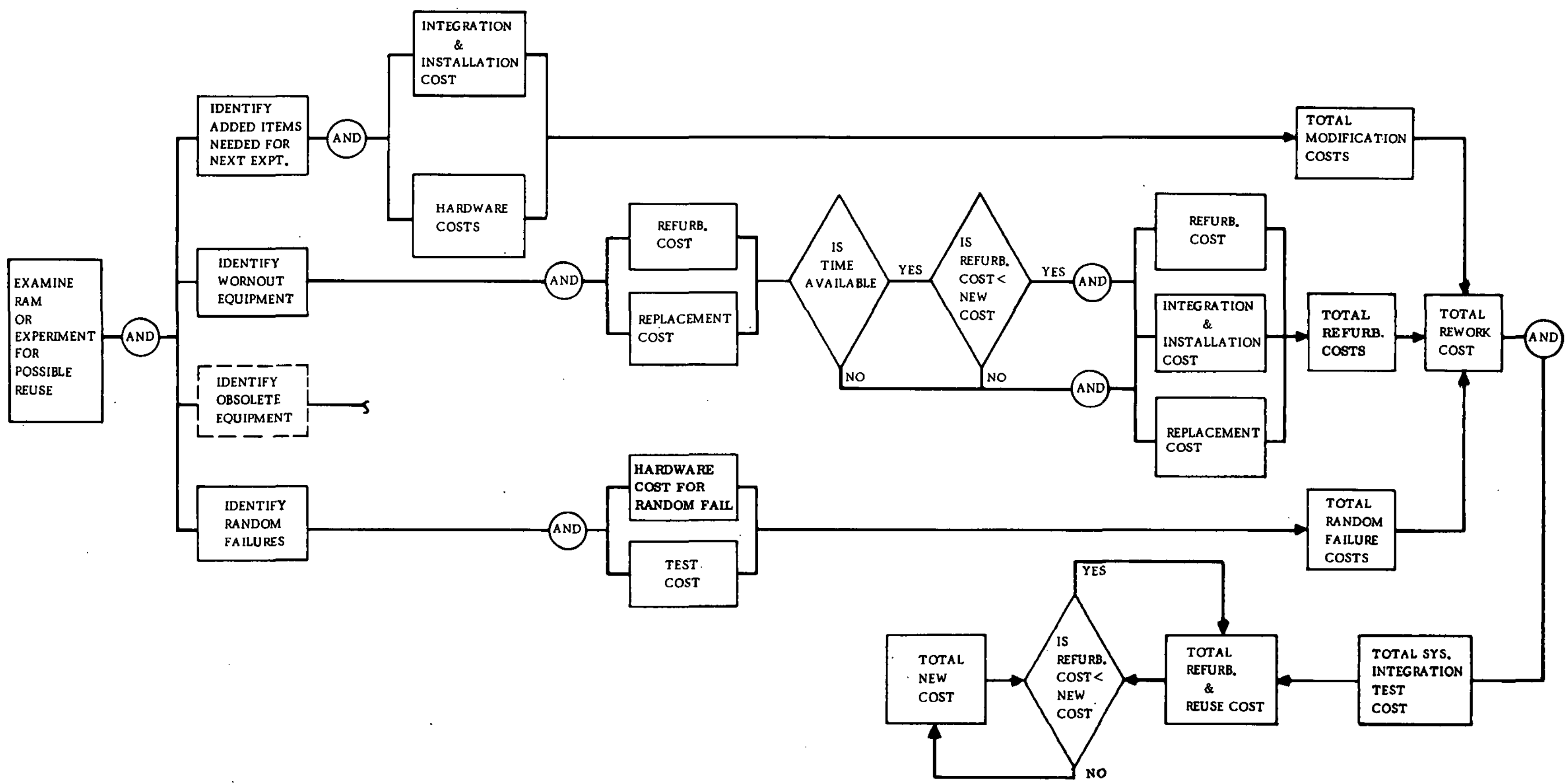

Figure 7-5. RAM Payload Carrier Refurbishment Analysis Logic

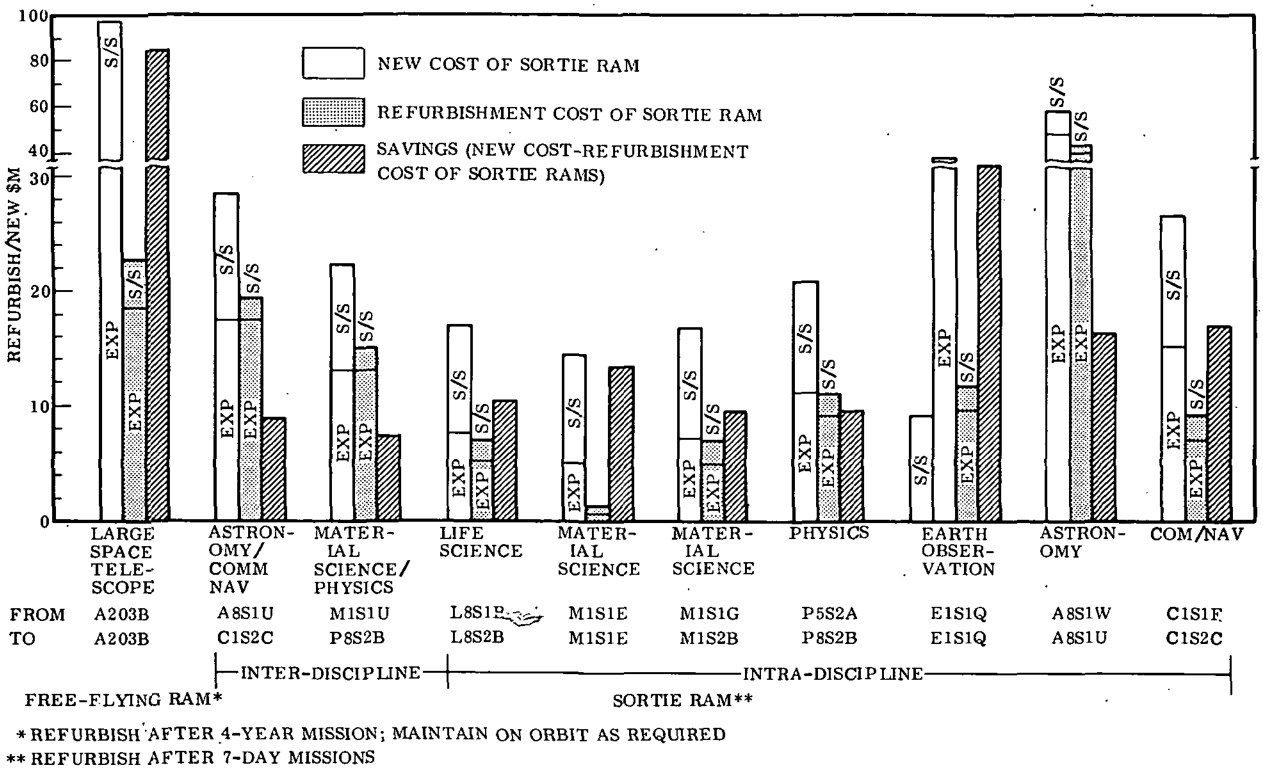

Figure 7-6. RAM Payload Carrier Refurbishment and Reuse Study Results

Refurbishment would be accomplished each time the RAM/payload module returns to earth following completion of a mission as shown in the REP (Figure 1-1), which was adopted for this analyais. For the free-flying RAM (large space telescope) a four-year mission is indicated before returning to earth, during which period on-orbit maintenance is performed. Sortie missions are nominally of seven-day duration. Examples of refurbishment costs include battery cell replacements, recoating of thermal radiator panels, general service and cleanup of the module, overhaul and repair of worn out items, new (added) components required for the next mission, pro rata share of random failure costs, and installation and test costs.

The results of all RAM payload carrier/payload configurations studied showed large cost savings by refurbishing RAM payload carriers rather than replacing them. The average savings for all sortie RAMs studied varied from 27 to 92 percent (55 percent average), which is \$14.3M average per sortie. Assuming these average results are representative and projected to include all 97 sortie missions scheduled in the REP, the total savings for sortie RAMs would be about \$1.4B.

7.2 SYSTEM SAFETY

The system safety effort impacted the program during all study tasks. A complete system safety analysis was performed for RAM elements, subsystems, and operations. It included safety criteria and requirements, hazard analysis, identification of hazardous

materials and safety design drivers, development of remedial action, and identification of residual hazards.

Although not all of the safety recommendations could be accepted, the original requirements were satisfied. For example, the preferred safety procedure was to prohibit experiments capable of generating biological or toxic contaminants from being attached to the orbiter or space station. While this was unacceptable for other reasons, alternative action was taken: the experiment was locally isolated by a hatch between RAM element and the orbiter or station.

The following additional sources were analyzed to develop safety requirements and evaluation criteria:

a. Performance Requirements for the Space Station Program (Modular), McDonnell Douglas.

b. Phase B Program Definition Study, Modular Space Station, MSC-03696.

c. Space Station Safety Study, MSC-00189.

d. Shuttle Orbital Applications Requirements (Midterm review), McDonnel Douglas.

e. Three previous RAM Phase A concept studies.

In general, the entire subject of RAM system safety as related to experiment operations is of foremost concern. Payloads are not defined accurately enough at this time to permit an adequate safety analysis. Even at this stage, however, the necessity for thorough safety surveillance of the experiment portion of any future operational program is clear. The following criteria show some of the elements with which a follow-on safety effort must be concerned.

a. RAM experiments will include self-contained protective devices or provisions to protect the orbiter or space station from experiment-induced hazards.

b. All fluids used in experiments that can produce toxic fumes must be provided positive means for preventing accidental release of toxic fumes into the breathable atmosphere.

c. Provisions must be made to detect and warn of any harmful airborne trace contaminants that are potentially releasable from experiment instrumentation, materials, or specimens.

d. Experiment-generated microbiological contaminated waste material shall be disinfected as close as possible to its source prior to storage, processing, or disposal.

e. The environmental control system for animal experiment containment volumes will be designed to ensure that no bacteria, odor, or physical contaminants can be introduced into the pressurized RAM, orbiter, or space station atmospheres.

f. The design of animal experiment containment volumes will ensure that there is no unremedial befouling of crewmen, the pressurized RAM, orbiter, or space station as a result of crew interface in animal care, feeding, or other experimental activity.

g. High-pressure tanks, pressure lines, and volatile gas or propellant tanks necessary for experiment operations will be located outside of, and as remote as possible from, critical equipment and primary pressure shells of the pressurized RAM.

A safety analysis of the RAM element subsystems was performed. A portion of the analysis consisted of a system safety review of all FMEAs. A major concern was to verify the satisfactory performance of critical functions, which were defined as functions whose failure could cause death, serious injury, or loss of a module. As such, the safety goal was to achieve performance following two equipment failures. Degraded or alternative means of operation were permitted if they met the stated objective.

The following safety provisions had a major impact on RAM element subsystem design.

a. Capability must be provided to allow operation with all pressure hatches (orbiter and RAM payload carrier) open or closed. This led to an independent EC/LS subsystem for a sortie RAM as the most practical solution.

b. Passenger seats in the RSM must be located such that they provide minimum possible egress time for occupants to reach the orbiter interface. (Tests of the selected arrangement indicated payload crew egress from the RSM to orbiter while on the launch pad could be accomplished within 18 seconds.)

c. The optimum safety locations for externally mounted tanks are:

   1. High-pressure gas tanks at the aft end (opposite the orbiter interface) of the modules.

   2. Cryogenic tanks at the aft end of the modules, with cryogen oxygen tanks as remote as possible from cryogen hydrogen tanks.

   3. Hydrazine tanks as remote as possible from cryogen oxygen tanks and at the aft end.

   4. Tanks at the docking end of any module to be protected by "bumpers" from possible collision damage.

   (The number of tanks required exceeded the space available at the aft end of the module, thus requiring some tanks to be located at the forward end.)

d. An emergency intercommunication system, independent of the normal system, must be provided.

e. Emergency lighting, independent of the primary power system, must be provided.

f. Emergency equipment must be provided for countering atmospheric contamination. Face masks and an emergency oxygen system is required.

g. A backup means of survival is required to counter loss of pressure. Pressure suits, PLSS, and umbilical connections are the recommended solution.

h. To prevent crew death or serious injury, all subsystems must provide for a minimum safe level of operation of critical functions after two failures.

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 8

LOGISTICS

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SECTION 8

LOGISTICS

Logistics support for the RAM program entails the consideration of, planning for, and providing elements of support that will enable the RAM experiment program to be accomplished effectively and economically. The support elements span the life of the program and include the following:

a. Maintenance

b. Supply Support

c. Support Equipment (GSE)

d. Support Documentation

e. Transportation

f. Packaging and Handling

g. Personnel and Training

h. Support Management

8.1 LOGISTICS CONCEPTS

The preceding logistics items have been examined in an effort to reduce the operational program costs. The major RAM program activities include manufacturing, experiment integration, maintenance, and launch. Variation in the number of geographical locations where these activities could be accomplished has a marked effect on the program operational costs. Although more than one location could be used for payload integration and maintenance, the study of the logistics elements was confined to combining activities to minimize the number of separate geographical locations. The following is an examination of the logistics elements as affected by the reduction in operational locations.

8.2 MAINTENANCE

Maintenance includes checkout, servicing, status monitoring, inspection, fault isolation, replacement, modification, and overhaul. The cost of maintenance is based on the number of manhours expended in the accomplishment of the task. The number of maintenance manhours at the launch location is the same regardless of the number of other sites; these manhours include those activities related to installation of the RAM payload carrier into the orbiter, and the resulting checkout and servicing required for launch. A maximum number of maintainance manhours are required to support a separate

location for payload integration since maintenance personnel assigned to subsystem monitoring and operation will be required to prevent deterioration of the RAM element subsystems during payload integration. Another disadvantage to a separate integration site is the longer ground turnaround time due to maintenance and experiment integration functions being accomplished in tandem rather than concurrently, such as would be possible when combining experiment integration and maintenance at one location. The total maintenance manhours are minimized when the preventive maintenance activity during experiment integration phase is eliminated.

8.3 SUPPLY SUPPORT

Supply support includes the timely provisioning, distribution, and inventory replenishment of spares, repair parts, and special supplies such as RAM element subsystem consumables. The cost of supply support is directly related to the number of locations where a supply support inventory of material is maintained. In the concepts under consideration, an emergency supply of spares, as well as subsystem consumables, will be required at the launch site. Minimizing this investment in emergency spares can be achieved by utilizing a high-speed transportation system and a rapidly responsive inventory control system. Accomplishing payload integration and RAM payload carrier maintenance at the manufacturing site not only has the advantage of fewer locations for stocking spares and repair parts, but also permits keeping stock levels at an absolute minimum by depending on the manufacturer's capability to fabricate the needed part or, in an emergency, remove the part from production stock or from a module on the assembly line.

An important consideration in supply support entails the cost of obsolesence of spare parts resulting from incorporation of changes. Combining activities at the factory not only reduces the total number of spares required, and therefore the least number of possible obsolete parts, but also represents a potential for an efficient spares rework program because of the manufacturer's fabrication capability.

8.4 GROUND SUPPORT EQUIPMENT (GSE)

Ground support equipment must be provided at each location where such functions as transportation, inspection, experiment integration, payload installation/removal, launch, and maintenance are accomplished. The quantity of GSE required for the RAM program is related to the number of locations where the above functions are accomplished. A decrease in quantities of equipment, as a result of a higher utilization rate for each item or set of equipment, can be achieved by limiting the number of locations where ground operations are accomplished. Accomplishing payload integration and maintenance at the factory permits the highest utilization rate and consequently the minimum dollar investment in GSE. Prototype operational equipment, when appropriate, could be fabricated for use as manufacturing tooling thereby reducing tooling costs. The use of the support equipment in manufacturing will, in effect, serve as a test program for debugging and proofing the equipment, thus reducing the extent of the development test program required for operational support equipment.

8.5 SUPPORT DOCUMENTATION

Support documentation includes all technical data required to logistically support the operational RAM program. A major portion of the task entails the development of formal documentation to describe operations, maintenance, overhaul and structural repair of end items, GSE, Line Replaceable Units (LRUs), and components. The cost of data is only slightly affected by the number of locations where data is required. The cost of printing increased quantities is negligible compared with the cost of research, writing, editing, illustrating, and the initial printing.

The combining of manufacturing, payload integration, and maintenance functions at one location reduces support documentation to a minimum. Formal documentation could be limited to that data required at the launch site for the operations concerned with the installation of the RAM payload carrier. Data to support a combined maintenance and integration activity at the manufacturing site can be limited to the data necessary for management of the maintenance program plus an expansion of the manufacturing and engineering paperwork to include troubleshooting and checkout procedures.

8.6 TRANSPORTATION

The major cost associated with transportation is represented by the cost of intersite air flights required to transport modules and payloads. Separate locations for maintenance and payload integration functions represent a minimum of intersite flights for transport of modules and payloads. Locating these functions at the manufacturing site is slightly less costly because the cost of transporting equipment and spares between the factory and maintenance site is eliminated.

8.7 PACKAGING AND HANDLING

Packaging and handling includes the special preservation and packaging that is necessary to assure that modules, assemblies, subassemblies, components and expendables retain the required level of reliability during transportation, storage and maintenance. The packaging and handling element is relatively unaffected by the number and locations of the facilities for manufacturing, experiment integration, maintenance and launch. The reduced numbers of spares, as described in Section 8.3, could, in effect, reduce the task of packaging and preserving spares; however, this is not a significant cost item.

8.8 PERSONNEL AND TRAINING

Skilled personnel are required for manufacturing, payload integration, maintenance, and support of launch operations. A training program utilizing on-the-job-training, classroom instruction, and training equipment is required to achieve the

necessary proficiency. The cost of the training program is affected by the number of personnel to be trained and the extent of the training equipment required. The number of personnel to be trained can be kept to a minimum by transferring the knowledge gained during manufacturing to the payload integration and maintenance operations. The manufacturing and development test programs permit a high degree of on-the-job-training on real hardware, thereby reducing the requirements for training equipment. The maximum combination of functions, with a consequent minimum personnel and training program cost, is achieved by combining manufacturing, experiment integration and maintenance at one location.

8.9 SUPPORT MANAGEMENT

The support management task entails the organizing, controlling, scheduling, accomplishing, and reporting the status of the logistics elements in a cost effective manner and in harmony with all other interfacing programs and systems. An inventory control system is required to provide the configuration and maintenance status and the location of all payloads, RAM elements, spares, spare parts, and expendables for purposes of program management. The system must be supported by a disciplined and accurate configuration control and documentation system. The requirements for data recording and transmission are such that electronic data processing will be required to provide timely data for program management.

The cost of the inventory control system is related to the number of locations where material is located. Minimizing the number of separate spares locations as well as the number of locations for RAM elements and payloads will result in a minimum cost inventory control system.

Isolating the RAM program operation activities from space shuttle and the launch facilities to the maximum extent possible will reduce possible interference with non-RAM-project related functions. Consolidating the RAM program functions of manufacturing, payload integration, and maintenance at one location permits development of efficient management techniques. The shorter communication lines permit rapid reaction and response to program contingencies. Scheduling problems can be resolved rapidly and least cost approaches can be used in program problem solutions.

8.10 CONCLUSION

Consideration should be given to minimizing the number of different geographical locations required to perform manufacturing, payload integration, maintenance, and launch operations for the operational RAM program. With a low production rate for RAM elements, a more stabilized labor force and a higher utilization of personnel can be achieved by performing payload integration and maintenance at the production facility. Such an arrangement would also be compatible with a low-funding program that would progressively increase RAM element capabilities through incorporation of subsystem changes.

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 9

DEVELOPMENT REQUIREMENTS

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SECTION 9

DEVELOPMENT REQUIREMENTS

This section defines the programmatic requirements critical to the conduct of RAM Project Phase C/D that were not discussed in previous sections. Test, manufacturing, and facilities requirements are summarized herein with detailed description of these and other programmatic requirements provided in RAM Project Phase C/D Project Development Requirements, Convair Aerospace report GDCA-DDA72-010.

9.1 TEST

Test requirements identify the test program and test hardware that are significant cost or technical factors in achieving the success criteria for an acceptable family of RAM project elements. Testing of the RAM payload carriers, their subsystems, and interaction with ground support equipment (GSE) will be performed to assure an orderly development program, minimize program cost, and meet the 10-year reusable life cycle objective.

9.1.1 TEST PHILOSOPHY AND CRITERIA. Test philosophy and criteria have been identified at the RAM payload carrier system and subsystem level. At the system or project level:

a. Test/verification requirements will be traceable to the RAM project or contract end item specifications.

b. Nondestructive testing will be emphasized.

c. Automated data management and onboard checkout will be used to minimize test hardware duplication and as a cost-saving mechanized test/verification method.

d. Final validation of operational checkout procedures will be made during simulated ground and flight operations, with each procedure being accomplished at lowest acceptable level.

e. Safety testing will be considered throughout the test program.

Subsystem-level test requirements include development, qualification, and acceptance testing elements of the test program. Development testing will consider maximum use of analysis to minimize the scope of development test requirements. The requirement for qualification testing will be based on the criticality of potential effect of a failure. Criticality 1 (as defined in Section 7) hardware will require qualification testing, whereas Criticality 2 items will be verified by the certification process. (Certification is a compilation of data to be used for assuming component suitability for acceptance and/or flight. The type of data includes any or all of the following: analysis and development, integration compatibility, similarity, acceptance, and qualification test data.

The compilation of data may include one or more of these to verify that the specification and/or design requirements are reasonably assured. If qualification test data is required, it would consist of specific conditions not satisfied by other means.) Criticality 3 items will maximize use of similarity and analysis as prime method of qualification. Results from all testing will form the basis of reliability assurance. Special testing specifically for reliability will be avoided. Acceptance testing is a part of quality assurance program requirements, and its success criteria are concluded from development and qualification testing as well as design performance requirements.

9.1.2 TEST REQUIREMENTS. In the development of the RAM system and subsystems, engineering tests will be identified for verifying the design approach. RAM payload carrier subsystems testing will pursue the laboratory, breadboard, functional, evaluation, simulation, environmental, and dynamic tests. Ground support equipment (GSE) will undergo engineering development tests as required, and will be used in subsystem testing where possible to minimize duplication of test equipment for the combined systems level test and for verification of GSE suitability. Combined subsystems testing for engineering development will be accomplished in the avionic integration facility. Data from subsystem testing will be used to design avionic/nonavionic simulation and stimulation, such that displays and controls and data bus traffic will simulate conditions expected from various mission profiles.

Integration of payloads to verify physical and functional interfaces with the RAM payload carriers will be accomplished in a three-step operation: 1) verification of interface requirements by simulation techniques for RAM element acceptance, 2) a prototype RAM payload carrier/payload simulation at the combined subsystems level, and 3) RAM payload carrier/payload integration simulation in the flight articles.

System-level test integration of the RAM payload carrier with the space shuttle and flight test will be accomplished at the launch site. The RAM project contractor will be responsible for identifying the test and facility requirements necessary to verify compatibility of the RAM system with the interfacing system. Contractor test requirements will be specified for each RAM element for mating with the shuttle orbiter vehicle and for prelaunch, launch, flight mission, and postlanding phases of integration and mated testing.

9.1.3 TEST ARTICLES. Major test articles and their intended use are shown in Table 9-1.

9.1.4 TEST DOCUMENTATION. RAM project test documentation will consist of test requirements, plans, procedures, analysis reports, and a data bank, as illustrated in Figure 9-1. It will cover all levels and types of testing from component development and qualification through end-item acceptance. All significant test requirements, plans, and procedures will be consolidated and correlated into a Unified Test Plan.

Table 9-1. Test Article Hardware

Test Article	Hardware Configuration	Type Test
No. 1 Pressurized RAM	Primary and Secondary Structure	Ground vibration modal survey Static load to ultimate (nondestructive) Pressure test to ultimate
	Add Thermal Insulation Add Environmental Control Subsystem	Acoustic transmissibility and absorption Thermal vacuum test Pressure cycles 15 psi ΔP 40 flights x 3 cycles x factor of 4 = 480 cycles (nondestructive)
	Add RSM Prototype Subsystems	Combined subsystems
No. 2 Free-Flying RAM	Primary and Secondary Structure	Ground vibration modal survey Static load to ultimate (nondestructive)
	Add Prototype Subsystems Less Solar Cells & RCS Thrusters	Combined subsystems
No. 3 RAM Pallet	Primary and Secondary Structure	Ground vibration modal survey Static load to ultimate (nondestructive)
	Add Prototype Subsystems	Combined subsystems
No. 4 32-Foot RAM Payload Module	Primary and Secondary Structure	Ground vibration modal survey Static load to ultimate (nondestructive) Pressure test to ultimate
No. 5 Avionic/ Nonavionic Equipment Mockup	Wiring and plumbing breadboard of each RAM-peculiar element with prototype hardware	Subsystems and combined subsystems interface development with computer simulation

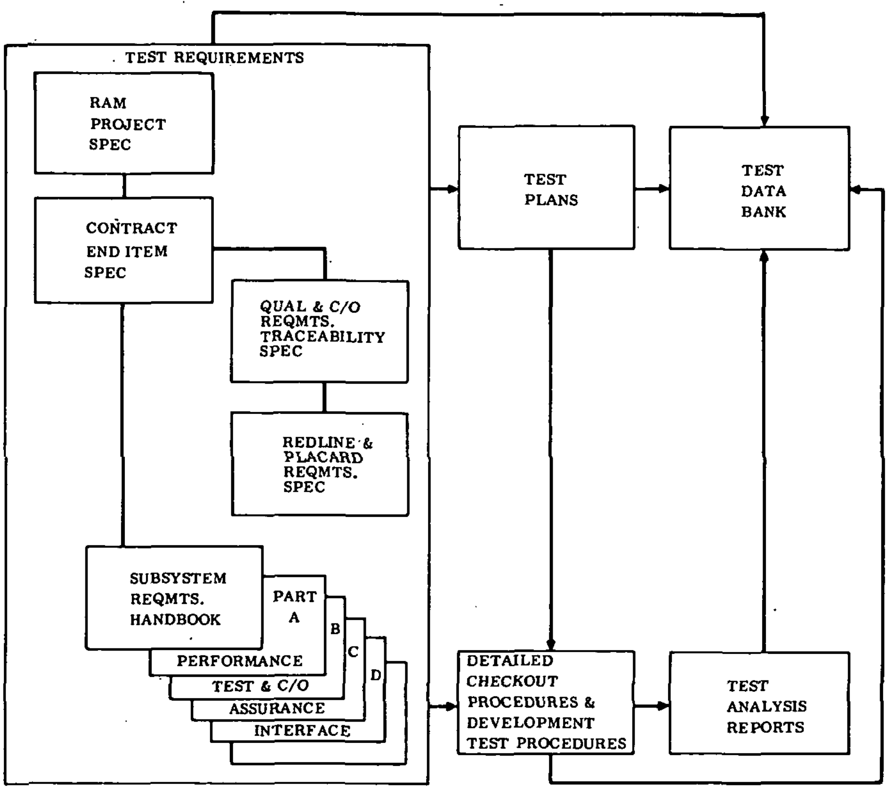

Figure 9-1. RAM Test Documentation System

9.2 MANUFACTURING

The RAM payload carriers, because of their unusual character and usage, introduce circumstances of production, logistics, and facilities that are unique to the industry. The manufacturing task involves a product having features of a production line and a "custom" shop. The RAM project engineering drawings present a design having detail elements of material, form, and size well within the range of existing equipment and manufacturing competence. The diversification of the end-item configurations and high degrees of re-usability, reliability, and maintainability coupled with a low production rate are unique features and require fresh concepts of planning, tooling and manufacturing management.

The manufacturing process has a direct impact on the cost of the project. In most airframe programs, characterized by hundreds of identical units produced over many years, the cost of manufacture can be 90 percent of the total program cost. In the RAM project, the manufacturing costs may be 25 percent or less. Since ten or fewer of each RAM payload carrier will be produced, it is not cost effective to design and build elaborate and complex tools or assembly fixtures to minimize unit recurring cost. The small number of RAM payload carriers demands that the tooling and assembly fixtures be simple, inexpensive, and in minimum numbers.

9.2.1 RAM PAYLOAD CARRIER DESCRIPTION. The family of RAM payload carriers consists of the pressurized, unpressurized, and free-flying RAMs. The pressurized RAM derivatives (sortie RAM, RSM, and RAM payload module) have structural commonality that simplifies the manufacturing task. Cylindrical sections are 14 feet in diameter and either 10 or 24 feet in length, which facilitates fabrication using common tooling. Also, the forward and aft conical sections that weld to the cylindrical section are structurally similar. Pressurizable (free-flying) RAMs have similar construction to the pressurized RAM, but their diameter is 12 feet instead of 14 feet, and their experiment end closures vary for each of the payloads. Interior furnishing and installation arrangements are peculiar to the assigned mission, but the differences do not cause a departure from the manufacturing approach established for the pressurized RAM. The assembly sequence and flow time are similar to those of the pressurized RAM, and the facilities and assembly tooling can be designed to accept and service both diameters.

The unpressurized RAM (pallet) has distinct characteristics isolating it from the pressurized and pressurizable RAM production line, but the open stringer/frame concept is conducive to simple manufacturing techniques and tools.

9.2.2 MANUFACTURING BREAKDOWN AND FLOW. A typical RAM payload carrier manufacturing breakdown is shown in the standard "tree" arrangement of Figure 9-2. The manufacturing sequence chart, Figure 9-3, shows the sequence of assembly of the pressurized RAM and unpressurized (pallet) RAM with mission-peculiar equipment installations. For simplicity and brevity, only the principal subassemblies and compo-

nents are shown. Most details comprising these RAM elements are not significantly unique to warrant special tooling or manufacturing study. In the manufacturing low of the pressurized sortie RAM (Figure 9-4) all secondary hardware is installed prior to the cleaning operation. After cleaning and throughout its operational life, the RAM element will be constantly threatened with the entrance of external contamination. Since there is no known totally satisfactory method for removing dust, dirt, or other foreign material from the RAM payload carrier, stringent precautions must be taken to prevent their entrance. These precautions must begin at some point in the manufacturing sequence such that initial cleaning occurs after all drilling, grinding, etc. for the attachment of all secondary structure. Beyond this point, the RAM payload carrier interior must be kept clean (class 10,000 per Federal Standard 209). This point bears emphasis. The manufacturing process, and no doubt the design, is impacted by the necessity to preclude the entrance into the RAM payload carrier interior of any type of contaminants.

9.2.3 MAJOR MANUFACTURING TOOLS. There are three major tools used to assemble the primary structural assembly. The cone assembly fixture (Figure 9-5) is used in the welding of five components: the three 120-degree skin segments and the fore and aft rings. The joints are buttwelds and involve trim fitting, joint preparation, welding, and inspection. All except the inspection are accomplished on one fixture.

The sidewall weld fixture is comprised of two principal components, illustrated in the working position in Figure 9-6. The first is a large, cantilevered holding device for containing the assembly elements for welding. The second is a gantry structure containing a work housing that holds the equipment required to complete a weld.

The holding device is designed to cradle and clamp skins and longerons in position for performing the welding task. Capability of adjustment, separating, moving adjacent pieces together, and rotating the work is provided. Containing the work in a true circular shape is not a requirement. The purpose of this device is only to hold and move the pieces without strain or distortion.

The gantry structure is mobile and straddles the holding device. It is electrically operated and the speed adjustment allows control of welding speeds as well as rapid traversing for other uses. Across the bridge of the gantry is a cross-traversing mechanism for moving a work housing, which contains a welding unit, a machine head, an X-ray gun, and room for two operators. The unit is on steel rails that extend beyond the limits of the fixture, allowing crane accessibility for loading components and removing the completed cylinder.

To accomplish the welding of two butt joints that attach the cone assemblies to the cylinder, a universal fixture is to be used. The fixture shown in Figure 9-7 holds the mated components in the correct alignment and provides cutter accessibility when machining and pre-

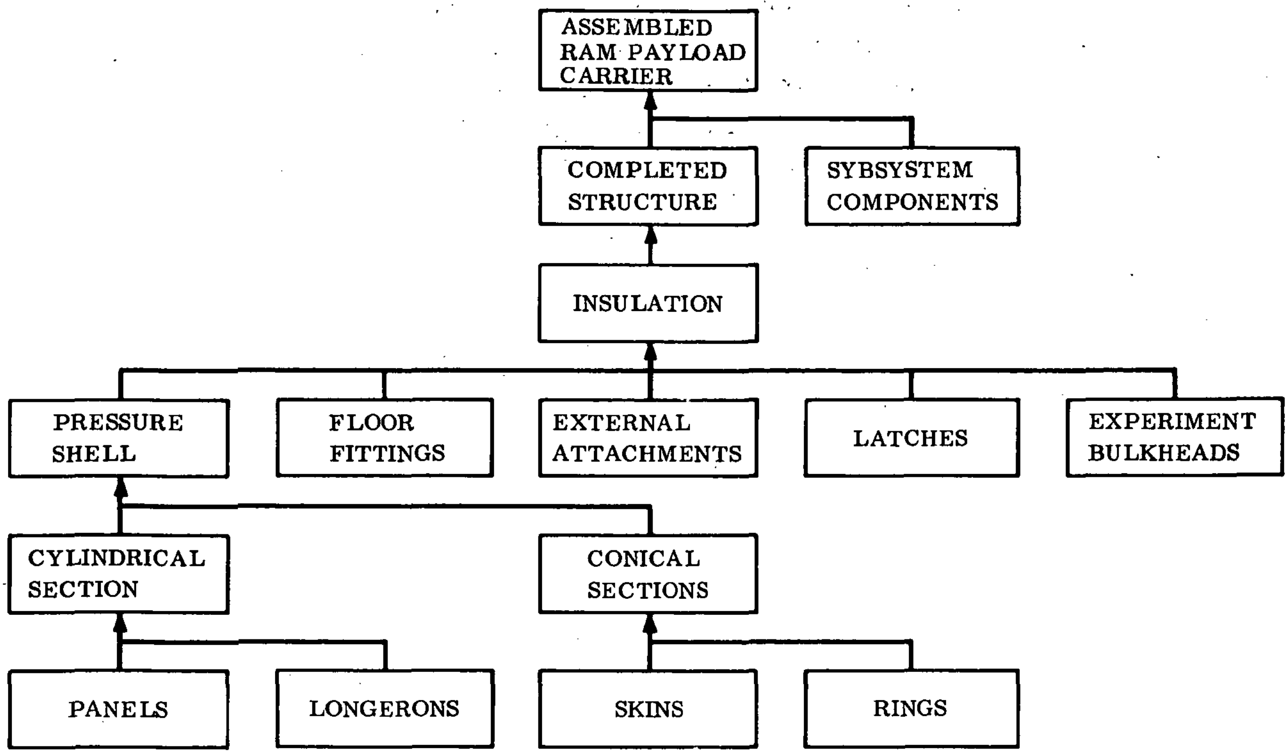

Figure 9-2. Typical RAM Manufacturing Breakdown

paring the part edges for welding. It can also rotate the assembly past the cutter or welding heads. It is to be used in conjunction with the gantry unit provided for the cylinder fixture. Since this fixture has all the requirements of holding and rotating the assembly needed for subsequent manufacturing tasks, it is logical, in view of the low production rate, to expand its application. Consequently, the fixture is designed for mobility. After welding, the assembly will be retained on the fixture and transported to an isolated pressure testing area for pneumostatic testing, returned to the factory for primary assembly work, then to a wash room for cleaning, and finally to another area for insulation installation. The assembly is then removed from the universal fixture at the final assembly area.

The fixture is built on a heavy base structure similar to that of a railroad flat car. The wheels are pneumatic tired. Jacks are provided to hoist the structure off the tires when work is being performed on the assembly. The cylinder, when encase in external rings, rests on power-operated rollers that provide rotation speeds suitable for machining and welding. Each end of the fixture has trunnion units for holding the end cones in alignment with the cylinder. They can turn in unison with the cylinder rollers or may, at will, be free turning. These units have lateral movement capability for mating the three main elements. Lateral motion is sufficient to handle all ranges of length of the RAM payload carriers. When welding the cones to the cylinder, the cones are attached to the trunnion units by tooling adapters that interface to the cone door rings. These adapters functionally simulate vehicle closures so that, upon welding, the assembly is sealed shut for subsequent pressure testing.

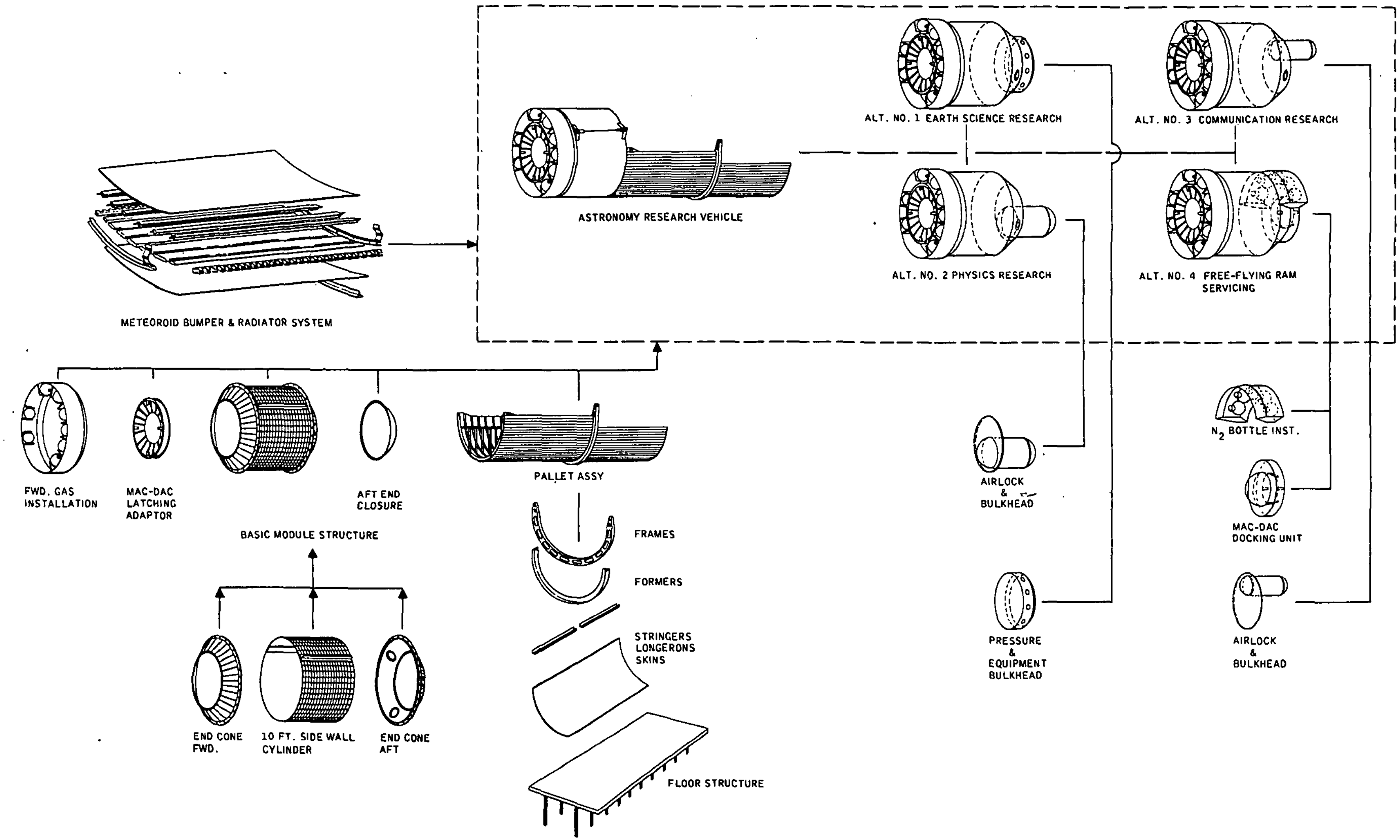

Figure 9-3. Manufacturing Sequence

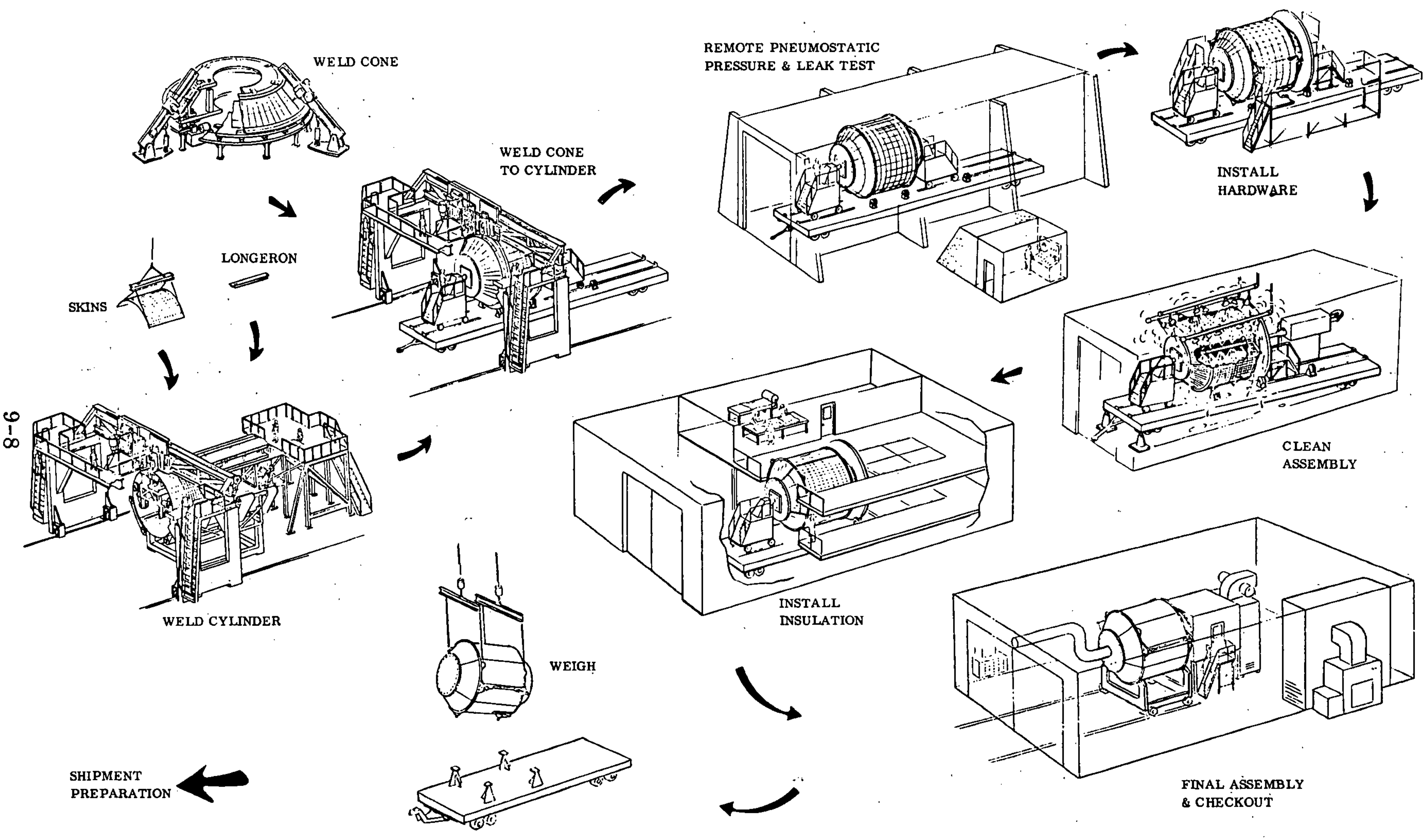

Figure 9-4. Structure Flow

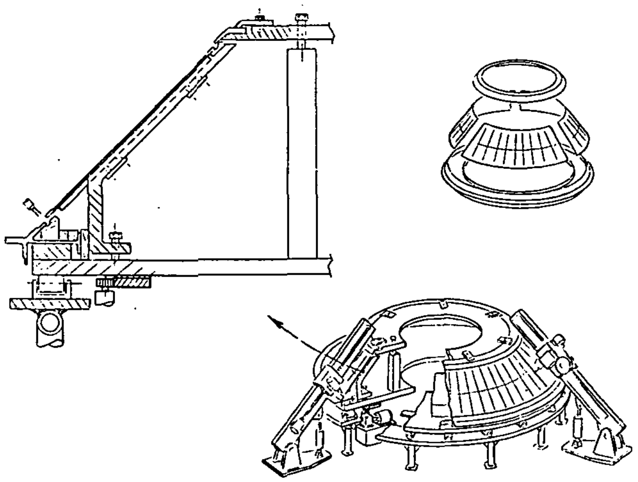

Figure 9-5. Cone Assembly Fixture

9.3 FACILITIES

RAM project facility requirements have been identified for development test, manufacturing, integration of the payload with the RAM payload carrier, prelaunch, postlaunch, and training. The description and sizing of the facilities were only at a conceptual level, and no alternatives were investigated. Facilities are assumed to be fixed, permanent installations consisting of building, structure, and equipment together with the accessories necessary for performing its intended tasks.

9.3.1 DEVELOPMENT TEST FACILITIES. Development test facilities, including test laboratories, computer facilities, and major test article facilities, are those installations necessary to support development tests. Major test facilities identified to support the RAM project based on the test requirements include:

a. A structural static load test facility to verify RAM payload carrier structural subsystem design parameters and safety factors.

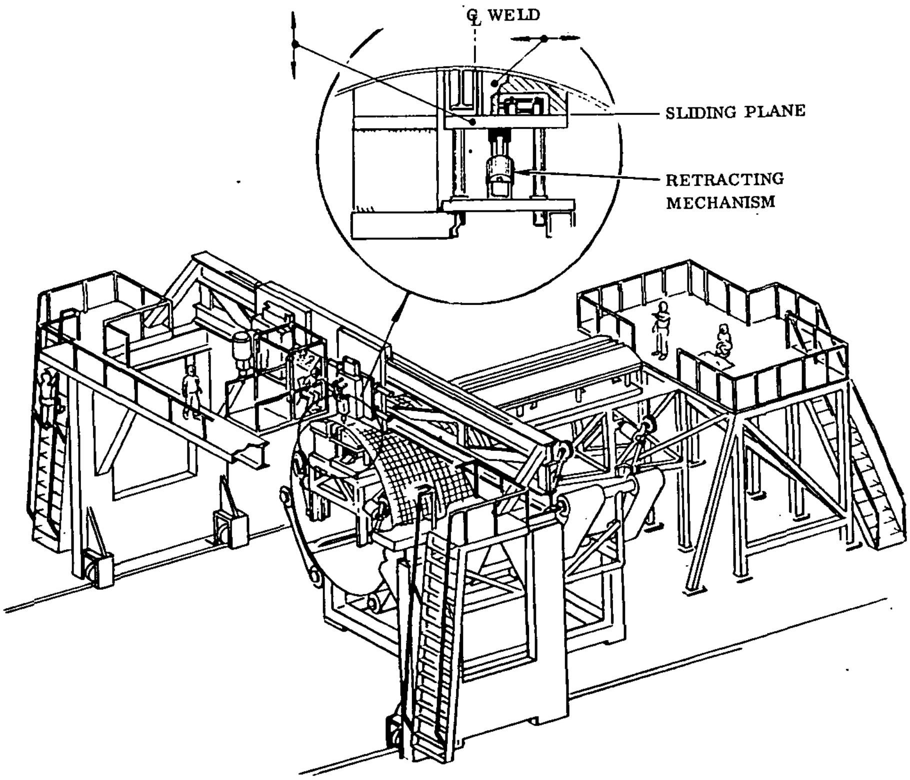

Figure 9-6. Sidewall Weld Fixture

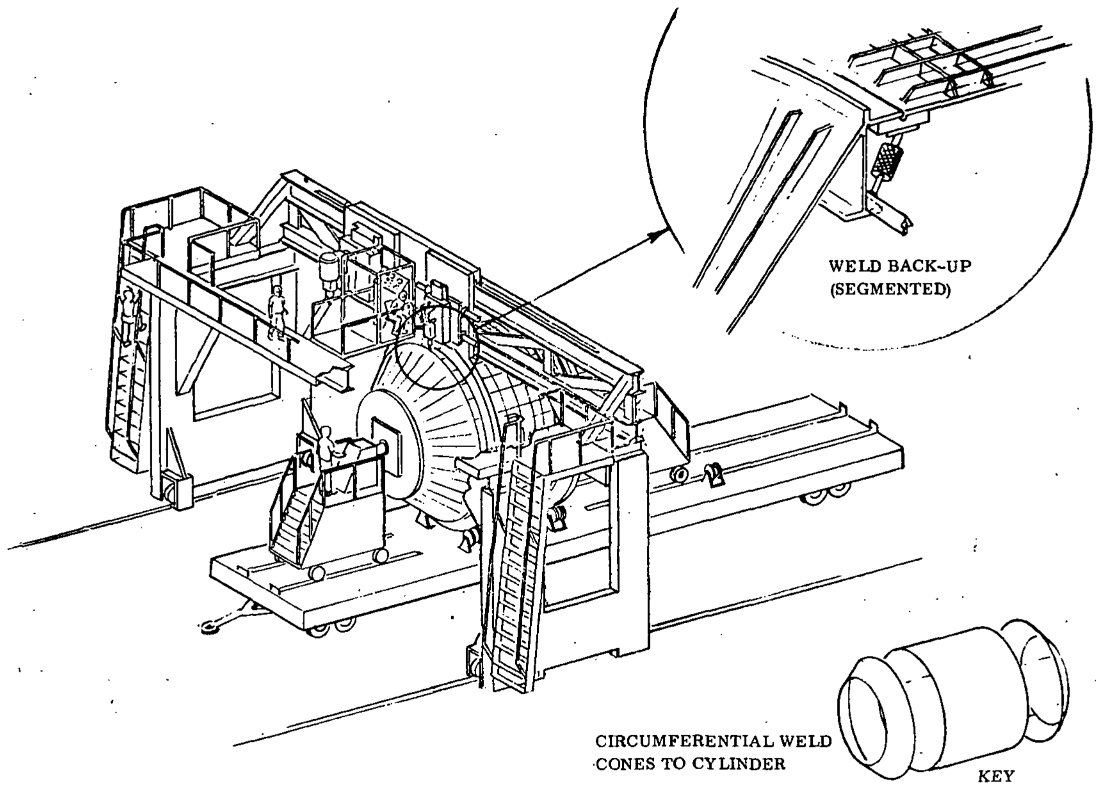

Figure 9-7. Circumferential Weld Fixture

b. A structural dynamic test facility for determining RAM payload carrier structural subsystem deflections, natural frequency modes, stiffness, and other structural parameters.

c. A launch acoustic environment facility to determine the effect of the very high level of noise present during launch on RAM payload carrier structure, acoustic transmissibility, and absorption.

d. A thermal test facility to verify the coefficients and parameters of the thermal control subsystem elements of the RAM payload carrier under simulated space environment.

e. A guidance, navigation, and control test facility that simulates the environment for space conditions critical to the performance capabilities of the GN&C subsystem.

f. A *compatibility integration test facility for verifying the integration of avionic* with the nonavionic subsystems, developing operating procedures, and performing electromagnetic interference tests. This facility must provide access to a computer data and control system and provide a hard RF link from the test area to a ground station.

9.3.2 MANUFACTURING FACILITIES. The manufacturing facilities required for the RAM project are similar in many respects to previous man-rated space hardware programs, with the addition of two requirements: low early-year funding and extensive reuse capability. Major or unique manufacturing facilities required to support the manufacturing requirements are:

a. A structural welding facility for structural assembly of the RAM payload carriers. The area must be completely enclosed and incorporate a controlled environment.

b. A pressure test facility for proof-pressure testing of the welded RAM payload carrier structure.

c. A structure cleaning facility for thoroughly cleaning both the exterior and interior of the RAM payload carrier after structural proof testing.

   A special high-pressure liquid cleaning system and a hot, dry, clean air system will be incorporated within the facility for cleaning and drying the structure.

d. An insulation area for the application of the multi-layered insulation to the exterior of the RAM payload carrier structure.

e. A final assembly facility, which consists of a cable-supported vinyl plastic enclosure, to maintain class cleanliness of 10,000 to support the installation of sterile or packaged equipment within the RAM payload carrier. Conditioned air must be supplied to ensure a complete screening action throughout the area.

9.3.3 INTEGRATION FACILITIES. Integration facilities are areas where the RAM payload carrier and the payload are brought together and the payloads are installed in the payload carrier, debugged, and tested as necessary. In addition, interaction of the RAM payload carrier/payload with the operational ground communication and data recording/control equipment can be accomplished. These integration facilities may have to provide the capability to support the testing of unique payload carrier and/or payload equipment, e.g., testing of essentially zero-g devices while in earth's one-g field.

9.3.4 PRELAUNCH PREPARATION FACILITIES. Since RAM payload carriers can arrive at the launch site either as an integrated module with payloads installed and tested, direct from the factory without payload, or with payloads installed from the maintenance and storage facility, the prelaunch preparation facility must be flexible and capable of being adapted for each of these conditions as well as a large number of payload types. This facility requires similar capability as the integration facilities, but with the additional capability to support all RAM payload carrier configurations and their payloads.

9.3.5 <u>POST-LAUNCH FACILITIES</u>. Post-launch facilities are those required after landing of the orbiter with the RAM payload carrier and up to entering the prelaunch operations. There are two areas in this category: a safing area that can be integrated with the orbiter vehicle safing area, and a maintenance/refurbishment and reconfiguration area. The maintenance/refurbishment and reconfiguration area can be integrated into the prelaunch preparation facility, since the requirements for the two facilities are similar.

9.3.6 <u>TRAINING FACILITIES</u>. Special facilities will be required throughout the life of the RAM project for the training of mission and payload specialists. This training will require many of the facilities used for general astronaut training as well as space shuttle training facilities. It is assumed that these facilities exist and are available for use by RAM project. A minor amount of RAM project-oriented equipment, such as hatches and work stations, will be supplied to this essentially space shuttle facility.

RESEARCH AND APPLICATIONS MODULES (RAM) PHASE B STUDY

SECTION 10

SUPPORTING RESEARCH AND TECHNOLOGY

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SECTION 10

SUPPORTING RESEARCH AND TECHNOLOGY

The RAM program elements are characterized by their ability to satisfy overall system requirements while staying within the current state-of-the-art.

The preliminary design of the various elements for the selected RAM payload carrier concepts was based, to the extent that it was practical and cost-effective, on proven technology and hardware that is currently available or expected to be available in a time frame compatible with RAM project requirements.

Thus, there is no question of the technical feasibility of the proposed implementation associated with the RAM elements. There are, however, particular areas that offer the potential for cost reduction by means of improvements in reliability, maintainability and/or performance.

The proposed supporting research and technology (SRT) items are associated with Communication/Data Management and Guidance, Navigation, and Control.

10.1 COMMUNICATION/DATA MANAGEMENT

All requirements of the Communications and Data Management subsystem can be satisfied with the current state-of-the-art except for the requirements associated with payload A303B, Advanced Solar Astronomy Observatory. These requirements (the simultaneous data handling of seven 220 Mbps channels) would have to be handled in a brute-force fashion, i.e., the paralleling and synchronizing of a large number of tape recorders. The following candidate SRT task is proposed in order to achieve the designated benefits regarding data handling for A303B:

a. Substantial reduction in equipment weight.

b. Reduction in equipment cost.

c. Significant improvements in reliability and maintainability.

10.1.1 <u>HIGH RATE DIGITAL BUFFER STORAGE (TAPE RECORDER)</u>. In projecting the performance of a tape recorder, the technology that exists within the United States, as a whole, was considered. Therefore, although the major manufacturers in each area were consulted, the prediction of future hardware design was not limited to one manufacturer's design. This approach is necessary, since one tape recorder manufacturer (Borg-Warner) uses a peripheral drive to achieve higher tape speed without unduly stressing the tape, another (RCA) uses a track density of 50 tracks per inch of tape width, and virtually all manufacturers concur that 30K bits/inch packing

density is feasible within two years. Table 10-1 lists some of the significant characteristics of tape transports that are representative of the state-of-the-art.

The Electronic Industries Association Working Group on Instrumentation Magnetic Tape Recording has proposed a high density track configuration of 42 tracks per inch of tape width. Each of these techniques to increase the bandwidth exacts a penalty in bit error rate; but, it is not unreasonable to project (with SRT) that within five years all the above cited techniques can be combined with a resultant error rate of 1 part in 10^6. This will yield the following performance for an advanced (1978) spaceborne tape recorder:

$$\text{Maximum Rate} = 300 \text{ inch/sec} \times 30 \times 10^3 \text{ bits/inch} \times 100 \text{ tracks}$$

$$= 1.8 \times 10^{11} \text{ bits (5000 ft of magnetic tape)}$$

The development of high-rate digital buffer storage will significantly reduce the cost and weight of the recording/buffer storage equipment needed for particular payloads of the space experiment program. The use of high resolution imaging sensors in disciplines, such as Astronomy and Earth observations generate high speed bursts of data (up to 220 MB/S per channel) that normally cannot be handled in real time by processing equipment or data transmission links; buffer storage is the answer to this problem.

Magnetic tape recording is the most promising for high rate digital buffer storage; significant performance improvements have been achieved in recent years, and more are in the offing. For intermediate and mass storage applications, the tape recorder has the best performance when the systems are evaluated on the basis of cost/bit, bits/pound, energy/bit, and bits/inch^3.

10.1.2 TECHNICAL PLAN. The objective of this SRT would be to develop and demonstrate the concept feasibility of a spaceborne magnetic tape recorder for high rate digital buffer storage. The input rate should be 900 MB/S with a total storage capacity $\geq 1.8 \times 10^{11}$ bits at a bit error rate (BER) < 1 in 10^6.

10.1.3 TECHNICAL APPROACH. The technical approach would emphasize the development of high speed tape transports, high density track spacing, and high bit packing densities through coding modulation. Extreme packing densities will require more sophisticated de-skew processing. This can be partially avoided by using word formats that occupy 1/2 or 1/4 of the available tracks (word lengths of 50 or 25 bits). The deskew circuits for each word will then only have to correct for skew across 50 or 25 percent of the tape width. There is high confidence that the proposed approach can be successful in developing a machine to meet the objectives. As noted in status above, the techniques proposed are under development and have individually demonstrated performance. The technical approach outlined simply combines the best features of several independent research and development efforts.

Table 10-1. Comparison of Near-Term Magnetic Tape Transports

Contractor/Model	RCA/ERTS	RCA/ERTS	RCA/SH	Ampex/AR 700	Ampex/AR 1700	Ampex/AR 500	Leach/MTR 7000	Borg-Warner PERT
Number of Tracks	1	100	1	28	28	1	12	30
Recorder Operation	Helical Scan	Longitudinal	Helical Scan	Longitudinal	Longitudinal	Rotary Head	Longitudinal	Longitudinal Newell Drive
Tape Speed (IPS)	Effectively 1964	40	Effectively 1333	60	120	Effectively 2000	120	Up to 1000
Tape Length (ft)	2000	2000	2400	7200	9200	2200	9200	2400
Tape Width (in.)	2	2	1	1	1	2	1	1/2
Bandwidth (MB/Sec/T)	15-20	1	5	1.0	2.0	5.5	2.0	6-15
Packing Density (KB/I/T)	7.5-10	25	Analog	20	20	Analog	16.7	15
Weight (lb)	74	74	50	48	72	115	100	50
Size (ft^3)	2.3	2.3	1.0	1.3	1.5	2.6	3.7	1.0
Power (watts)	90	90	75	175	220	?	700	150
Signal/Noise (db)	42	30	38	20	20	22	22	24
Data Capacity (bits)	2.4×10^{10}	6×10^{10}	Analog	4.8×10^{9}	6.2×10^{10}	Analog	2.2×10^{10}	1.3×10^{9}
Availability	In Development	In Development	In Development	Used on Martin Skylab Program	In Production-Not Space Qualified	In Production-Not Space Qualified	Wright-Patterson AFB	In Development
Estimated ROM Cost	180K per Flight Unit 800K for Development Costs	180K per Flight Unit 800K for Development Costs	80K per Flight Unit 650K for Development Costs	120K per Flight Unit 650K for Development Costs	120K per Flight Unit 650K for Development Costs	120K per Flight Unit 650K for Development Costs	60K per Flight Unit 600K for Development Costs	160K per Flight Unit 800K for Development Costs

10.1.4 RESOURCE REQUIREMENTS. Resource requirements should be estimated by requesting proposals from specialized industrial concerns, e.g., Ampex, RCA, Borg Warner, etc.

10.1.5 TARGET SCHEDULE. Development should be complete approximately two years prior to the expected flight data for the astronomy payloads requiring this capability (A303B).

10.2 GUIDANCE, NAVIGATION, AND CONTROL

The basic requirement of the star tracker is to provide an attitude reference capable of supporting an all-attitude measurement for a Free-Flying RAM to ± 30 arc-sec or better. The requirements can be satisfied by using either two wide-angle, double-gimbaled or three fixed-head star trackers in conjunction with a strapdown rate gyro package.

10.2.1 FIXED HEAD VERSUS GIMBALED STAR TRACKERS. Current, state-of-the-art, double-gimbaled star trackers can operate with stars of (visual magnitude) $M_V = 4$ or brighter with accuracies of 10 arc-sec or better. The principal disadvantage in the use of gimbaled star trackers lies in their use for long duration missions; i.e., their relatively poor reliability (mean-time-between-failures of 12,000 hours), thus requiring frequent unscheduled servicing.

Using fixed-head trackers of the same sensitivity ($M_V = 4$) and operating on the same star population with the same accuracy requirement, it has been determined that 20 eight by eight-degree field-of-view, fixed-head trackers would be required to obtain all attitude coverage. (See TS-4270-01, Free-Flying RAM GN&C Predesign Trade in Appendix A of Volume III, Technical Data Document). This is not a practical system because of the large number of trackers involved.

10.2.2 TECHNICAL PLAN. The objective of the proposed SRT activity is to develop a star tracking system having an all-attitude measurement accuracy of ± 30 arc-sec or better and a lifetime compatible with the mission duration of the Free-Flying RAMs with astronomy payloads (approximately five years).

10.2.3 TECHNICAL APPROACH. Fixed-head trackers sense and electronically image the star pattern within their fov. This image is matched against a stored star catalog by a suitable pattern recognition algorithm to determine the attitude of the unit. The number of units required is a primary function of tracker fov and star brightness sensitivity.

As the star tracker instrument sensitivity is increased, more of the total star population becomes visible. Table 10-2 lists the quantity of reference stars available as a function of star brightness. A rapid rise in available reference stars is evident as sensitivity is increased. The increase in population has two effects: 1) an advantageous effect is the increase in star density per unit area that reduces the number of

Table 10-2. Stellar Population Versus Limiting Visual Magnitude*

Limiting Visual Magnitude, M_V	Reference Star Population Increment	Reference Star Population
-2 to + 1	12	12
+ 1 to + 2	31	43
+ 2 to + 3	110	153
+ 3 to + 4	312	465
+ 4 to + 5	1,014	1,479
+ 5 to + 6	3,277	4,756
+ 6 to + 7	10,081	14,837
+ 7 to + 8	24,819	39,656
+ 8 to + 9	113,737	153,380
+ 9 to + 10	100,017	253,397
+ 10 to + 11	4,141	257,538

* These data represent catalog stars in the Smithsonian Astrophysical Observatory Star Catalog.

fixed-head units required and 2) a disadvantageous effect is that computer storage requirements increase such that a pattern search or image match can be accomplished. If the computer is ground based, the impact of this disadvantage is greatly reduced. Because of the availability of communication links, ground basing the computer would be recommended for RAM with fixed-head trackers. Periodically, the tracker would be sampled. Visible stars coordinates would be transmitted to the ground. The ground computer would perform the pattern search and transmit back the RAM vehicle attitude.

A further reduction in pattern recognition can be realized by limiting the image matching to that portion of the celestial sphere being covered by the star trackers.

The approach to determining the number of fixed-head trackers required relies on data of References 1, 2 and 3. The final results are presented in Table 10-3, which contains the basic information leading to the selection of the number of fixed-head trackers.

Based on the above analysis, an eight by eight-degree fov and sensitivity to $M_V \leq 6.35$ were used as fixed-head tracker requirements. This selection requires pattern matching considering a total star population of 7000. The expected accuracy for this field of

Table 10-3. Number of Required Fixed Head Trackers

Tracker fov (degrees)		6 × 6	8 × 8	10 × 10		
Area (steradians)		0.0109	0.0194	0.0304		
Accuracy (arc-sec) (1)		21.6	28.8	36		
4π viewing		1150	648	413		
Tracker Sensitivity ($\leq M_V$)	Star Population	Number of Trackers Required for Two Stars Within fov			Half-Cone Angle (degrees)	Half-Cone Area (Steradians)
3	153	94.8	53.3	34.1	33.577	1.048
4	465	37.8	21.2	13.6	21.006	0.417
4.7	1,064	15.75	8.87	5.67	13.521	0.174
5	1,479	11.3	6.27	4.07	—	0.125
6	4,756	3.51	2.02	1.26	—	0.0388
6.35	~7,000	2.39	1.34	0.858	—	0.0264
7	14,837	1.125	0.633	0.404	—	0.0124

(1) 0.1 percent of fov. This instrument accuracy is believed to be conservative for the 1978 and 1982 time frames of the free-flying RAMs.

view is satisfactory; it is expected that the accuracy could improve significantly because of advances in the state-of-the-art of sensor technology in a time frame compatible with the current Free-Flying RAM IOC dates of 1978 and 1982.

Table 10-3 shows that the number of trackers required for two stars of M_V 6.35 to be within the fov is two. By increasing this number to three, the attitude accuracy about the boresight line is enhanced by the use of two angularly-separated units.

The significant characteristics of fixed-head and gimbaled trackers are presented in Table 10-4.

A cost comparison of fixed-head versus gimbaled trackers was made for varying numbers of trackers to assess the effects of the increased reliability due to redundancy of each case. The results of this comparison are presented in Table 10-5. The added costs due to expected failures are included in the comparison.

Table 10-4. Fixed Head and Gimbaled Tracker Characteristics

Characteristic (Per Unit)	Fixed Head* (8 x 8) degree	Gimbaled ± (40 x 87) degree
Weight (lb)	20	40
Size stowed/operate (ft^3)	1.1/1.1	1.5/3.5
Avg. power (watts)	5	23.7
MTBF (1000 hr)	60	12
Life (1000 hr)	20	10
Cost ($1000)		
Recurring	150	290
Non-Recurring	750	0

* (1-20) arc-sec accuracy, 6.35 mv sensitivity, 6-inch optics.

From the resulting cost comparison, it is seen that the increased reliability resulting from redundancy is cost effective for either type of tracker. However, the cost advantage is strongly in favor of the fixed-head tracker when the costs associated with expected failures are considered.

10.2.4 RESOURCE REQUIREMENTS. Based on the preceding considerations, the fixed-head star tracker approach was selected. This approach requires the development of a more-sensitive unit ($M_V \leq 6.35$) together with an automated pattern recognition capability, which is expected to be accomplished in a ground-based computer.

The estimated development cost for the improved fixed-head tracker is $750,000. No estimate is available at this time for development of the required pattern recognition capability.

10.2.5 TARGET SCHEDULE. Development of the improved star trackers can be accomplished within four years after go-ahead. It is expected that improved sensors will be available, based upon projected improvements in the state-of-the-art, by 1976.

Development of the pattern recognition capability for stars of $M_V \leq 6.35$ over the celestial sphere, together with the necessary computer logic, can be achieved within three years after go-ahead.

Table 10-5. Fixed Head and Gimbaled Tracker Complement Comparison

Complement Characteristic	Fixed Head (1) (8 x 8 degree)			Gimbaled ± (40 x 87 degree)			
Mission Time (2)	43.8 K hr or 5 years						
Number	3	4 (3)	5 (3)	2	3 (3)	4 (3)	5 (3)
Weight (lb)	60	80	100	80	120	160	200
Size (ft^3)	3.3	4.4	5.5	7	8.5	10	11.5
Avg. Power (watts)	15	15	15	47.4	47.4	47.4	47.4
MTBF (1000 hr)	20	40	60	6	12	18	24
Cost ($1000)							
Recurring	450	600	850	580	870	1,160	1,450
Failure (4)	1,930	962	645	6,450	3,230	2,160	1,620
Subtotal	2,380	1,562	1,495	7,030	4,100	3,320	3,070
Non-Recurring	750			0			

(1) (1-20) arc-sec accuracy, 6.35 mv sensitivity, 6-inch optics.

(2) Average of three to seven year variation in free-flying RAM mission time.

(3) The quantity above the minimum is assumed stowed.

(4) Failure cost is based on cost impact per failure (evaluated by Convair Aerospace reliability as 883K for the shuttle supported mode) x mission time/complement MTBF.

10.3 REFERENCES

1. L. A. Kleinman and R. A. Archart, An Analytical Approach to Determination of Stellar Fields of View, NASA report TR-R-257, March 1967.

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